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ABSTRACT

This document reports the results of a study on the feasibility of training smog check mechanics in California via hands-on verification of mechanics' ability to inspect and repair vehicles. The reviews of the research literature that compare the learning effectiveness of different delivery media tend to support the position that in learning, the medium itself is not the critical factor. The bulk of the research indicates that maintenance training can be effectively delivered with actual equipment trainers, 3-D simulation, and computer-based instruction. The investigation focused on videodisk delivery systems and found that they are at least as effective as other training media. Although reported costs for methods of training vary widely, videodisk systems can be cost-effective. The cost of acquisition of videodisk delivery systems is offset by the savings in delivery costs. The study concluded that computer-controlled videodisks can be effective in delivering maintenance training and simulation. Because of the elimination of instructors and the reduced training time required to complete coursework, videodisks provide the most cost-effective delivery method for hands-on mechanic training and verification testing. Following a comparison of various training models, simulation testing was recommended to test, certify, and license mechanics in California. (KC)

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HANDS-ON VERIFICATION OF MECHANICS TRAINING: A COST-EFFECTIVENESS STUDY OF VIDEODISC SIMULATION

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EXECUTIVE SUMMARY

INTRODUCTION

In May of 1986, the California State University system released a Memo of Understanding (#4), part of an Interagency Agreement with the California Department of Consumer Affairs, Bureau of Automotive Repair (#121A0077-B5), requesting

> *a study be conducted on the feasibility of training smog check mechanics via hands-on verification of mechanics ability to inspect and repair vehicles.*

That study was awarded in October of 1986 to the Media Resource Center, California State Polytechnic University, Pomona, through a competitive process conducted by the Bureau of Automotive Repair. This report represents the results and recommendations of the study.

EFFECTIVENESS

The reviews of the research literature that compare the learning effectiveness of different delivery media tend to support the position that in learning, the medium itself is not the critical factor. However, because of the many attributes of mediated instruction, individuals and organizations that conduct equipment training have been interested in media as an enhancement of, or substitute for, training on actual equipment and physical equipment simulators. Although this research is not without its criticisms, the bulk of the evidence indicates that maintenance training can be effectively delivered with actual equipment trainers, 3-D simulation and computer-based instruction. In order to integrate the positive attributes of these delivery media, investigations have centered on videodisc delivery systems.

Computer-controlled videodiscs can be an effective method for delivering training and creating simulations. Videodiscs have been found to be at least as effective as other media in educational, industrial, military and state governmental settings. In the particular context of this study, videodiscs have been found effective in the delivery of a wide range of maintenance training and simulation. They have been found as effective as classroom instruction, actual equipment training and 3-D simulators. Videodisc training has been shown to work effectively within the automotive industry in the delivery of training to auto mechanics. Finally, state agencies have used videodiscs in both their training and licensing functions.

COSTS

The costs of creating and delivering maintenance training are very poorly reported and vary widely. In addition, there is no uniform method for reporting costs. Often only "total" costs are reported for courses which can vary from several minutes to several days in duration. While generally acknowledged as unsatisfactory, the most common unit for reporting cost is the hour of student instruction. Costs can generally be divided into acquisition costs for software and hardware development and costs for actual instructional delivery. Consequently, while the total costs of a particular delivery system might equal those of another system, the internal costs may be allocated very differently between acquisition and delivery expenses.

The acquisition costs for actual equipment trainers and 3-D simulators is almost entirely dependent on the cost and complexity of the operational equipment. In addition, 3-D simulation costs vary widely according to the amount of computer-control. Usually 3-D simulation costs less than actual equipment. Computer-based instruction can take 200 to 500 hours and longer for the development of an hour of instruction. Costs for computer-based instruction vary with the amount of graphics and the complexity of interaction. Videodisc costs also fluctuate based on degree of interactivity, video production values, complexity of design and production, etc. Videodisc development costs range from $10,000 to $125,000 per 30-minute side, and between $3,000-$5,000 per finished minute.

The costs of acquisition of videodisc delivery systems is offset by the savings in delivery costs. Videodisc training usually requires no additional instructor salaries and can be housed in spaces smaller than are required for classroom instruction. The other large savings in delivery comes from the reduced time required by students to reach the same levels of achievement as in other methods. The general range of time savings reported for videodisc delivery over other methods is 23%-66%, with the average falling closer to the 30%-35% range.

CONCLUSIONS

Computer-controlled videodiscs can be effective in delivering maintenance training and simulation. Videodiscs are generally less expensive to acquire than actual equipment trainers or 3-D simulators, but more expensive than computer-based instruction alone. However, videodisc training provides opportunities for equipment simulation not available with computer-based instruction. Videodiscs are the least expensive delivery method because of the elimination of instructors and the reduced training time required to complete coursework. Videodiscs therefore provide the most cost-effective delivery method for hands-on mechanic training and verification testing.

However, throughout this study, the training tasks reviewed all focused on the communication of a well-known body of knowledge, upon which most experts had agreed, about a particular and specific piece of equipment or set of procedures, to a generally homogeneous and well-known audience. This is not the training task required of B.A.R. Rather, they are faced with the task of communicating an emerging and developing body of knowledge, upon which there is no general agreement, about a wide range of equipment and a variety of procedures, to an audience that varies greatly in age, aptitude, ability and experience. In addition, this training task must be performed with limited manpower, facilities, equipment and financial resources. Consequently, the best application of those resources would be in the development of standards of performance for mechanics and in the creation of a simulation testing procedure to verify the attainment of those standards.

COST ANALYSES OF TRAINING MODELS

The current method of delivering training and five new delivery models have been described and their costs analyzed. The models presented are only five of an almost unlimited number of permutations and combinations of training designs and delivery systems. However, these models represent a range of options that address the original problem noted in B.A.R.'s solicitation. This range is presented to give the Bureau a set of data upon which to draw as their needs dictate.

The current training, which constitutes the Base Costs, is a combination of classroom instruction enhanced by videotaped material and exercises in the use of automotive manuals. This training costs $103 per student. Model 1 shows the costs to the Bureau for the development of standards for automotive emissions testing and repair, and for the testing of mechanics. The total cost-per-student is $60. Model 2 assumes the completion of all the work specified in Model 1. Model 2 then adds to Model 1 the concept of "hands-on" simulation testing by videodisc. The total cost-per-student is $51. Model 3 simply converts the content, including all existing videotaped material, of the current qualification/ requalification B.A.R. courses into an individualized, self-paced format on videodisc. The purpose of this model is to illustrate the cost savings in delivery of training with videodisc technology. The total cost-per-student is $61. Model 4 creates an entirely new 16 hour, individualized, self-paced videodisc-based course from the task analysis standards and comprehensive testing discussed in Model 1. This model also incorporates the simulation testing of Model 2 and the economies of delivery of Model 3. The total cost-per-student is $67. Model 5 illustrates the costs for a 16 hour class using actual, full hands-on automobile engines, equipped with complete emission devices and connected to computers for control. The total cost-per-student is $335.

RECOMMENDATIONS

1. B.A.R. should no longer actually conduct mechanic training, but should continue to test, certify and license.

2. B.A.R. should test, certify and license mechanics through comprehensive "hands-on" simulation testing.

Therefore, this study recommends Model 2, "Simulation Testing", as being the most effective method of insuring a hands-on, quality control capability for B.A.R., provided in the most cost-efficient manner.

INTRODUCTION AND BACKGROUND

In May of 1986, the California State University system released a Memo of Understanding (#4), part of an Interagency Agreement with the California Department of Consumer Affairs, Bureau of Automotive Repair (#121A0077-B5), requesting

> *a study be conducted on the feasibility of training smog check mechanics via hands-on verification of mechanics ability to inspect and repair vehicles. The study should include recommendations on the most cost effective approach for conducting hands-on training, retraining and testing.*

That study was awarded in October, 1986 to the Media Resource Center, California State Polytechnic University, Pomona, through a competitive process conducted by the Bureau of Automotive Repair. This report represents the results and recommendations of the study.

In discussions with Bureau personnel, it was clear that their primary interest was a cost-effective method of verifying that mechanics can function at an appropriate level of competence within the actual vehicle environment, rather than only perform on the current paper-and-pencil examinations. Consequently, this investigation has concentrated on simulated and actual equipment systems for delivering training and testing. (The cost-effectiveness of other methods of delivering training and education are discussed in Appendix B.)

This report is divided into two major sections. The Review of the Literature contains a summary of the research literature and other appropriate documents on the effectiveness of training systems used to present equipment or equipment-related instruction. There is also a summary in this section concerning the available information on the expenditures required to produce and deliver equipment training. This review ends with a series of conclusions, reporting on particular cost-effectiveness or cost-benefit studies of equipment training systems and synthesizing information from the previous two summaries. The second major section of the report is the Cost Analyses of Training Models. This section details the base costs of the current B.A.R. training and testing system and then presents five other models of testing and training. The operation of each of these training models is described, along with charts presenting the actual cost analysis, and detailed notes on the origins of the costs, for each of the models. Finally, the report concludes with Recommendations, References and Appendices.

REVIEW OF THE LITERATURE

EFFECTIVENESS

The discussion of the literature available on the relative effectiveness of one method of delivering training over any other should begin with the caution often noted by Clark (1985, 1983) and Solomon (1979; Clark & Solomon, 1985). In brief, their essential argument seems to be that any training delivery system is only as effective as the initial training design. An effective training design that incorporates appropriate learning principles can be equally effective regardless of the delivery medium. What often confuses and confounds comparison studies on the effectiveness of different delivery systems is that some learning principles are more easily implemented by some delivery systems. For example, the principle of learner control, by which the learners set their own pace for instruction, is easily delivered by a self-paced slide-tape program or videodisc. It is more difficult, but not impossible, to incorporate some learner control into a group presentation by an instructor.

Another factor that clouds the effectiveness issue is speed of delivery. Some systems can deliver more information than others in the same amount of time. In addition, the conversion of learning materials from one medium to another for purposes of comparison often results in the redesign of the original materials for the comparison medium. Consequently, the results of the comparison are tainted by that redesign. The basic point is that these factors are not issues of effectiveness concerning the quality of learning, but actually issues concerning the costs and practicality of a particular set of delivery hardware and delivery circumstances.

The reviews of the research literature that compare the learning effectiveness of different delivery media to each other, and to traditional classroom instruction, tend to support the position that in learning, the medium itself is not the critical factor. These reviews (Campeau, 1974; Chu & Schramm, 1979; Jamison, Suppes & Wells, 1974; Molstad, 1974; Wilkinson, 1980a, 1980b) have found that there is no significant difference between media in their general learning effectiveness. Individuals can learn equally well from any medium. The advantages associated with the use of media, such as reduced learning time, user acceptance, enrichment and enlargement of the learning environment, learner control, individualization of learning, etc., reduce under analysis to questions of costs and practicality.

However, particular media do have attributes that assist particular kinds of learning (Solomon, 1979). Obviously the learning of images is enhanced by some form of photography; learning color-coded electrical wiring is assisted by color images; film or television can be helpful in analyzing motion; rapid, random access to material can be facilitated by videodiscs;

extensive drill and practice can be less tiresome with computer-based instruction, etc. (A fuller discussion of the particular capabilities of individual media is available in Appendix C.) Because of the many attributes of mediated instruction, individuals and organizations that conduct equipment training have been interested in media as an enhancement of, or substitute for, training on actual equipment and physical equipment simulators.

ACTUAL EQUIPMENT TRAINERS AND 3-D SIMULATORS

Equipment training, and in particular equipment maintenance training, has not been delivered very successfully through strictly written and oral methods. As might be expected, paper-and-pencil tests are not good predictors of the actual performance of maintenance personnel (Johnson, 1980). One of the largest maintenance training organization in the country, the military services, has attempted to correct this problem by using actual equipment trainers (A.E.T.) (O'Neil, 1985). An actual equipment trainer is operational equipment that has been provided with the necessary power, inputs and outputs in order to function in a classroom environment (Orlansky & String, 1981). While A.E.T.'s can be effective in maintenance training (Johnson, 1980; Orlansky & String, 1981), they have three problems: faults must be simulated by putting in "bad" components, a difficult and time-consuming process; the machines are often hard to maintain in the classroom environment; and A.E.T's are usually very expensive (Orlansky & String, 1981). By extension, these basic problems result in situations such as long training classes, reduced practice time because of limited availability of machines, etc.

In an effort to solve these and other related training problems, the military developed three-dimensional (3-D) equipment simulators, often called part-task simulators, to replace the use of actual equipment. Simulation, in general, can present novel problems, guide learning with prompts and hints, elicit performance, provide feedback on performance to the learner, evaluate performance by having the individual present solutions and present several additional problems for practice (Gagne & Briggs, 1979). While some reviews of the research literature have pointed out problems, such as the transfer of simulation training to performance in the work environment (Fink & Shiver, 1978; Johnson, 1980), reviewers generally conclude that simulation training is not significantly different when compared to A.E.T. (Orlansky & String, 1981; Pieper et al., 1984; Su Yuan-Liang, 1984; Schendel, Shields & Katz, 1978).

In the review conducted by Orlansky and String of 12 major military studies on electronics maintenance training conducted since 1967, all but one of the studies showed that the achievement of students with simulators was the same or better than students using actual equipment. One of these studies also tested students in on-the-job performance and found no significant difference between the simulator and actual equipment students. Simulator students also took 22%-50% less time to complete training than with A.E.T. Many of the simulators were connected to computers to provide various fault scenarios. While expensive in absolute terms, simulators were less expensive than the actual equipment (Orlansky & String, 1981). Su Yuan-Liang (1984) and others (Farr, 1986) conclude that the physical and structural fidelity of the simulator is not as important in determining training effectiveness or transfer of training to actual equipment as the dynamic use of the simulator and the structure of the training itself.

While these reviews note the lack of research on the actual transfer of learning from the training environment to performance on-the-job, Su Yuan-Liang reports that the costs of actual equipment failure, the time to failure and other constraints in the workplace greatly increase the difficulty of transfer-of-training studies. Consequently, a system of simulator training on a series of faults and simulator testing on a different series of faults is the generally accepted method of studying the transfer of training (Su Yuan-Liang, 1984).

Although the research is not without its criticisms, the bulk of the evidence indicates that maintenance training can be effectively delivered with actual equipment trainers and 3-D simulation.

COMPUTER-BASED INSTRUCTION

Along with the development of 3-D simulation, investigators have explored the possibilities and potential of the computer in maintenance training. As in the case of other media, reviews of the research literature have concluded that computer-based instruction (CBI) can be an effective method of delivering educational material (Kulik, Kulik & Cohen, 1980; Kulik, Kulik & Shwalb, 1986; Spuck, 1981). Reviews of research that have concentrated on the use of computer training in the industrial environment (Russ-Eft, 1985; Stammers & Morrisoe, 1986) and in the military (Orlansky & String, 1979) have also concluded that CBI can be as effective as conventional classroom training.

However, computer-based training is not without problems. Some of the reviews have noted that the software development and hardware costs for CBI can be very expensive (Dallman & DeLeo, 1977; Goldstein, 1980; Russ-Eft, 1985) and that some students have a negative reaction to working with computers (Orlansky & String, 1979; Russ-Eft, 1985). In a study that used the PLATO mainframe computer system for training vehicle maintenance personnel for the military, Dallman and DeLeo (1977) concluded that CBI was only appropriate for teaching some, but not all, the required skills. This limitation to particular skill training by computers was also noted by Goldstein (1980). One of the obvious deficiencies of CBI is the lack of reasonably-priced, photographic-quality images, either as stills or motion. Streibel (1985) has also criticized CBI for such things as limiting the mental landscape of the learner and shaping interaction to maximize only performance gains.

In addition to the general effectiveness of CBI in instruction, one of its most significant advantages is enhanced opportunities for testing (Russ-Eft, 1985). Feuer (1986) lists among those advantages immediate feedback, on-the-spot score reporting, the retention of scores on discs and the use of the computer as a simulation device. These advantages of computer testing have been successfully used by the PLATO mainframe system to offer the Federal Aviation Agency's private pilot certification examination for licensing (Anderson & Trollip, 1982).

Because of the problems of 3-D simulation, such as relatively high costs and the subsequent limitations on numbers of simulators, and the problems of CBI such as cost, user acceptance and limited presentation forms, other alternatives continued to be investigated. Since 3-D simulators were enhanced by the addition of computer-control (Orlansky & String, 1981), and since "wholeness" or physical fidelity to actual equipment did not appear to be required for simulators to be effective (Su Yuan-Liang, 1984), the next step was to create a simulator with the advantages of CBI but with additional visual and auditory reality. As recommended by Orlansky and String (1981), the potential of the computer-controlled videodisc system appeared to present a low-cost yet effective alternative. Recent research into training delivery systems and maintenance simulators has focused on the possibilities of the videodisc.

VIDEODISC TRAINING DELIVERY

Capabilities

A computer-controlled videodisc delivery system, usually referred to as a Level III videodisc (Daynes,1984; Parsloe, 1985), has several very important capabilities that make it attractive as a training device. In addition to storing and playing back video and text material, videodiscs can do rapid, random search and access; store up to 54,000 still pictures; play back clear still frames; play back stereo or dual-track audio; and permit the use of several input devices such as joysticks, keyboard, light pen, touch screen, graphics pad and others. Some particular hardware configurations can deliver audio during still frames and provide computer graphics overlaid on the visual images.

The result of these capacities is that videodiscs can permit extensive learner control of the pace and content of instruction, provide instant "customizing' of the instruction to fit the needs of a particular learner through diagnosis and branching instruction, provide immediate feedback on progress, monitor and record performance, provide audio in two languages, and are endlessly patient and non-judgmental (Hawthorne, 1986; Parsloe, 1985; Smith, 1987; Young & Schlieve, 1984). In addition, videodiscs can create simulations of equipment operation that preclude injury to persons or damage to actual equipment (Azia, 1986; Kerka, 1986).

General Effectiveness Studies

The reviews of the literature on the effectiveness of videodiscs in delivering education and training show the same trend in results as the general reviews of media use. That is, videodisc delivery was as effective, or more effective, that the delivery system to which it was compared.

In a review of 16 studies of videodisc delivery, DeBloois, Maki and Hall (1984) acknowledged the poor research quality of many of the studies. However, they were able to concluded that videodisc learners are "achieving scores which are significantly higher than learners using other approaches" (p.53). They also reported that learners preferred videodisc systems over conventional media.

Bosco (1986) reported on 28 research reports that included statistical tests. Of a total of 39 tests on the benefits of a training delivery method, 24 of the tests, or 61%, showed positive results for videodiscs. In an additional 23 cases that did not report actual statistics, 22 of the cases, or 96%, showed benefits for videodisc delivery. Bosco (1986) summarized the findings by noting that the primary benefits of videodisc delivery were reduced training time and improved user attitudes to training. There were generally no significant differences in achievement and no particular pattern in performance.

In the most recent review of videodisc literature, Smith (1987) also notes the generally poor quality of much of the research, but is able to conclude that "interactive video does appear to produce learning and in many cases appears to be superior to other delivery approaches" (p.7). Smith (1987) also notes that many of the studies show the logically expected outcome that the best performance is achieved with systems that have maximum learner control.

While there appears to be extensive use of videodiscs in vocational training, both in educational and industrial settings (Kerka, 1986; Oliver, 1985), very few effectiveness studies from these projects appear in print. As noted in the reviews (Bosco,1986; DeBloois, et al., 1984; Smith, 1987), the effectiveness reports that are available usually say very little about the conduct of the research. However, some of these studies are illustrative of the way in which videodiscs are being used in industrial training.

Balson and others (1985) reported on a videodisc study by the Medical Information Technology Research Group to train individuals to give intramuscular injections. The videodisc group showed an 8% increase on the same posttest criterion over the control group. The Southern Pacific Railroad has created a locomotive simulator that uses as many as 70 videodiscs to create the sights and sounds of the train, much like a flight simulator. The system uses very sophisticated software and has been effective (Stender, 1986). Conoco Oil Company has created a oil field drilling simulator that has been found effective in beta-testing, but with only 15 trainees ("Conoco tests", 1986). Videodiscs have been found effective in a welding simulation that used symbols instead of text ("No reading skills", 1986), and in a CPR simulation that used the manipulation of a manikin to control the training program ("Actronics markets CPR", 1983). Videodiscs have been found effective in mathematics education (Starr, 1986; "Vanderbilt evaluates", 1986), in delivering soft skills such as interpersonal training (Vidas, 1986) and in delivering technical skills such as the use of oscilloscopes and multimeters (Holzberger, 1987; Miller & Sayer, 1986).

Military Effectiveness Studies

While there is relatively few civilian research studies on the effectiveness of videodisc training delivery, the military has conducted extensive and generally well-executed research into simulation training by videodisc. The general reviews of the literature (Bosco, 1986; DeBloois et al., 1984; Smith, 1987) did not include much of this work. The military studies are important in the context of this report because many of them concern electro-mechanical equipment operation and maintenance. In addition, the studies were conducted within continuing training courses that allowed the use of control groups. Also, these existing courses were highly structured and often centered on actual equipment trainers or 3-D computer-controlled simulators.

In a study of training for an automated, data telecommunications center operator, a videodisc simulator was used in conjunction with limited access to the actual equipment (Vernon, 1984). The control group (n=74) received conventional training that included an average of 112 minutes on the actual equipment trainer. The experimental group (n=76) received the classroom portion of the training, an average of 106 minutes on the A.E.T., and 156 minutes of videodisc simulation. The experimental group performed better on the practice test, and completed the practice test and the performance test in significantly less time. There was no significant difference between groups on the final performance test (t tests, p<.05). These results were confirmed by Hull (1984) in a study of operator training that also used video simulation in combination with reduced time on actual equipment. In this study written tests, performance tests on actual equipment and acceptance measures all showed significant differences in favor of the video simulation (F tests, p<.05). Another study of operator training for a satellite communications ground station (Young & Toste, 1981) relied completely on videodisc simulation for the experimental group (n=27). The control group (n=24) was trained on the actual equipment. On an objective test, retention test, measure of confidence level and practical problems tests, there was no significant differences between groups (t tests, p<.05).

The results of research on maintenance training are very similar. Wilkinson (1982) reported on a study of training for radio receiver repair personnel. The experimental group (n=48) was trained with a combination of videodisc simulation and limited use of actual equipment. The control group (n=51) used actual equipment only. There were no significant differences between the groups on measures of cognitive learning, performance skill, and times to complete the total training and the performance test (F tests, p<.05). The experimental group using the videodisc simulation completed practices exercises on the actual equipment in significantly less time (F test, p<.01). These results for using videodisc simulation to augment actual equipment have been generally confirmed in another study with a videodisc electronics equipment maintenance simulator (Cicchinelli, Keller & Harman, undated).

In a study comparing a limited videodisc delivery system to a slide-tape method of training in a course on troubleshooting a field radio (King, 1982), the experimental group using videodisc (n=73) showed no significant differences with the control group (n=146) on a retention test (F test, p<.05). However, the videodisc group was significantly faster in reaching a mastery level of performance (F test, p<.05). In reports of two similar studies that compare traditional classroom training with computer-based instruction and with videodisc simulation reported that 100% of both the CBI and videodisc groups correctly completed the posttest performance problem, while only 25% of the classroom group were successful ("Evaluation", 1984; Gibbons, Lines & Cavagnal, 1983). In addition, the videodisc group in both studies completed the problem over 50% faster.

An extensive study was conducted comparing videodisc simulation only to actual equipment in a maintenance training course (Pieper et al, 1984). The control group (n=22) received the traditional course that included a 16 hour block of 72 practical exercises, This practice block was completed in two days. The experimental group received the same classroom instruction, but the practice time on the videodisc simulator was divided into 100 minute blocks at the end of each classroom day. Total course length for both groups was 72 hours (9 days). The videodisc group did significantly better on the troubleshooting test, but there was no difference on the time to complete the test. There were also no significant differences between the groups on a retention test, procedures test, or the projected job proficiency test that was use to test proficiency in the field on actual equipment (t test, p<.05). These findings of no significant difference in achievement were confirmed in another comparison of videodisc simulation to actual equipment training (Wilkinson, 1983).

Wilkinson's conclusion (1983) that videodisc simulation is as effective, or more effective, when compared to other delivery media, including actual equipment training, has been confirmed in other studies. These include the use of low-cost avionics simulation for pilots (Edwards, 1986), teaching interpersonal skills (Schroeder et al., 1982) and creating realistic urban situations to train tactical deployment (King & Reeves, 1985).

In recent conversations with the author, personnel at the headquarters of Army Extension Training, Ft. Eustis, Virginia, confirmed their confidence in the effectiveness of the videodisc delivery system (F. Giunti, interview, August 6, 1987; Col. Simonetta, interview, August 6, 1987). Some noted that one of the key elements in the effectiveness of videodisc delivery was the complete task analyses available for the courses which were converted to videodisc delivery (LTC. Woolever, interview, August 6, 1987). Most of military training is governed by complete task analyses upon which course curricula are based. Because the content of the traditional military training courses was known and understood, and those courses shown to be effective, the results of studies which found no differences between videodisc simulation and those traditional courses were compelling evidence for the effectiveness of videodiscs.

Automotive Industry and State Agency Use of Videodiscs

Computer-based and videodisc training have been used in the automotive industry for several years. Dallman and DeLeo (1977) reported on the use of the PLATO mainframe computer system to teach vehicle maintenance training in the Air Force. North Carolina Community Colleges developed a personal computer program with graphics and test recording for training on electronic fuel injection systems. Scores of students improved 61% between a pretest and posttest ("Development", 1985). In 1980, General Motors developed a network of 11,000 videodisc systems for several types of training (Daynes, 1984; Scott, 1982). However, these reports are primarily descriptions and do not provide any meaningful effectiveness information.

Because of changes to Federal safety regulations, both Chrysler and General Motors, in conjunction with the United Auto Workers, have developed videodiscs to provide hazardous material safety training. The GM training will be installed on 1,000 videodisc systems in over 140 manufacturing plants to reach 400,000 workers ("IMC, GM and UAW", 1986). The Chrysler videodisc will be used to train 85,000 employees in 31 manufacturing plants (Miller, 1987). There are no published effectiveness data available on either of these training programs.

Ford Motor Company has been very active in the use of videodiscs for training mechanics and other personnel at dealerships around the country. They have had Level II systems at dealerships since the early 1980's. This Level II system requires only a videodisc player and a monitor. While some interactivity is available between the learner and the system, the learning design is very simple, and the material is essentially a linear presentation. However, the apparent success of this system prompted Ford to develop and evaluate a more sophisticated, Level III videodisc training system (Short, undated; Short & Croke, 1986). Ford used Creative Universal, Inc.

to create and evaluate six courses. The evaluations were done at 16 dealerships, training 133 mechanics. Each of the six courses were designed to be the equivalent of an eight-hour course taught at the Ford training center.

The evaluation design did not use a control group or statistical analysis. Reports (Short, undated; Short & Croke, 1986) indicate an average gain of 22.4% from pretest to posttest scores for the mechanics in the test population. The range of time to complete each course was 41.1-80.8 minutes, with an average completion time of 59.9 minutes. In addition, the majority of mechanics and supervisors indicated a preference for the Level III videodisc system. The system that was tested had instructional strategies such as visual identification, touch-in-sequence, multiple comparisons of pictured objects, touch simulation of movement and hints to the learner. It was recently reported ("Ford parts", 1987) that Ford will make available 6,000 of these videodisc systems, The Sony Advanced View, to their dealerships in January, 1988. The advantages of this system are believed to be reduced administrative costs and mechanics downtime, and elimination of instructor costs, mechanics travel time and delays in training due to scheduling conflict (Short, undated; Short & Croke, 1986).

Finally, two studies of the application of videodisc training in state agencies are important to note. The state of Florida (Smith, 1984) created a package of 160 hours of instruction to train 500 new employees per year who work in the Aid to Families with Dependent Children program. The training package consisted of 9 videodisc sides, 78 floppy discs, and 8 reference manuals. Training occurred at 121 sites throughout the state. In the final examination, 50% of those receiving classroom training passed the examination compared to 66% passing of the videodisc-trained group. The videodisc group also finished the examination in 1/2 the time of the traditionally trained group. Total time to complete the training for the videodisc group averaged 120 hours, with a range from 60 to 194 hours (Smith, 1984).

The second report concerns the development of a state driver's license examination for both Arizona and South Carolina. The Arizona test has 34 questions about road conditions which are shown from the videodisc. The questions are asked orally in both Spanish and Vietnamese. This test was developed from a test bank of 200 questions on cars, motorcycles, small trucks and articulated vehicles in use in South Carolina ("Videodisc systems", 1987).

In summary, it seems clear that computer-controlled videodiscs can be an effective method for delivering training and creating simulations. Videodiscs have been found to be at least as effective as other media in educational, industrial, military and state governmental settings. In the particular context of this study, videodiscs have been found effective in the delivery of a wide range of maintenance training and simulation. They have been found as effective as classroom instruction, actual equipment training and 3-D simulators. Videodisc training has been shown to work effectively within the automotive industry in the delivery of training to auto mechanics. Finally, state agencies have used videodiscs in both their training and licensing functions.

COSTS

While the general reviews of the research literature that are interested in the cost-effectiveness issue have concluded that media in general and videodiscs in particular are cost-effective (Bosco, 1986; Orlansky & String, 1981; Russ-Eft, 1985; Smith, 1987; Wilkinson, 1980; Van der Drift,1981), little hard cost data are reported. Twenty years ago, in 1967, Schramm noted in The New Media: Memo to Educational Planners (see Appendix C) that the lack of data makes it difficult to evaluate

> the comparative educational efficiency of the new media in terms of cost....In the next five or ten years, let us hope, much better data and measures will be available.

In their discussion of maintenance training using simulators, conducted 14 years after Schramm, Orlansky and String (1981) continue to note that cost data have not been collected systematically. Consequently, they could only make broad generalizations about relative cost- effectiveness, rather than precise judgements between similar delivery systems. This lack of specific data concerning the actual costs of various training delivery systems is still a barrier to precise cost-effectiveness analysis.

In the case of videodisc delivery, both Mr. Ron Nugent, Director of the Nebraska Videodisc Design Group (interview, July 21, 1987) and Mr. Glen Hoptman, Director of the National Demonstration Laboratory for Videodiscs (interview, August 5, 1987) make the same points concerning the general lack of hard cost data. Videodiscs are a relatively new training media. Consequently, many of the early efforts in videodisc design and production had budgets that were not accurately estimated, and were grossly exceeded. Those individuals and companies responsible are not interested in publicizing that information. A second point is that most of the training videodiscs have been produced by private, for-profit corporations. Those corporations do not want to release what they consider to be proprietary costing information to potential competitors. Even the military, which is relatively forthcoming with historical cost data, will not discuss in any detail its methods of cost estimation because of the competitive bidding process for new contracts (Dr. L. Schall, interview, August 6, 1987). Finally, there appears to be a general feeling that since most videodisc training projects are unique, having few if any production components in common, the costs of any one project cannot be helpful in estimating the potential costs of another.

Because of the trend towards the use of videodisc systems in the research on maintenance training and simulation, discovered in the literature search on effectiveness, the cost data compiled here concentrate on actual equipment trainers and 3-D simulations in comparison to videodisc delivery, or on videodisc delivery alone. The costs of some of the other delivery possibilities are discussed in Appendix A. Because of the variability in the ways of reporting expenditures, the cost data have been grouped into comparative costs, individual program costs, program cost savings and costs of automotive training. Hardware costs and delivery system organization will be discussed within the context of specific comparison studies. In general, there are extreme fluctuations in hardware costs from manufacturer to manufacturer; fluctuations over time, as the microcomputer industry has grown; and fluctuations due to particular features that can be added to or deleted from the basic delivery equipment (Lockwood, 1986). Consequently, it is not worthwhile to concentrate on historical equipment costs.

COMPARATIVE COSTS

Costs for development and production are not reported in any uniform way. The major ways in which these costs are stated are dollars per videodisc side, dollars per hour of instruction and dollars per total course, but without a definition of what constitutes a "course". Some studies, primarily from the military, report total "manhours" in addition to, or as a substitute for, actual dollars. In addition to the incompatibility of the costing units, most of the available material that report costs do not describe the finished training product in sufficient detail to provide a sense of the relative complexity of the training task or difficulty of the videodisc production. Occasionally only parts of the costs of development and production may be reported for a project.

A costing survey of 175 videodisc courseware developers reported a range of development time per hour of instruction from 140 hours to 316 hours. This survey also notes that while the developers were not satisfied with the hour of instruction as a unit of measure for estimates, they had not found a better unit (Baechtel & Masconi, 1987).

In comparison studies, the development costs of other kinds of instructional delivery also can vary widely. Kochar and McLean (1985) found a range of development time, per instructional hour, of 2-10 hours for a lecture course, 10-50 hours for a self-study text, and 50-250 hours for computer-based instruction. Shavelson (1985) increases the range for CBI to 50-500 hours of development per hour of instruction. Sparkes (1985) reports an "average" time of development per hour of instruction of 100 hours for broadcast television, 200 hours for CBI and 300 hours for videodisc delivery.

In their review of studies that compare simulator training to actual equipment training, Orlansky and String (1981) found that in 7 of 11 examples, the item cost of a simulator was 60% or less of the cost of the actual equipment trainer. They concluded that simulator costs are generally less than actual equipment costs, particularly when the maintenance expenses and operational problems of actual equipment are taken into account.

Recent military comparison studies continue to show that simulation is less expensive than actual equipment training and to report a wide range of costs. Vernon (1984) compared the costs of training for an automated data telecommunications center operator between actual equipment and videodisc simulation. The actual equipment trainer cost $300,000 and training development cost $5,880, for a total of $305,880. The videodisc training cost $6,000 for the hardware system and $41,240 for the development of the single-sided videodisc, for a total of $47,240. Other Army document indicate that 2,440 hours were required to develop the videodisc for this simulation ("Manpower staffing", 1984).

In a study that attempted an extensive cost analysis, Hull (1984) reported that after 10 years and 3,900 students, the cost per student of actual equipment training would be $417, versus $74 for video simulation. The cost analysis included original equipment costs of $2,700,000 for a single actual equipment trainer compared to $69,440 for four video systems. The development costs of the simulation was $126,694, including 6,240 hours for a course writer and developer and 420 hours for data entry personnel. No costs were reported for video production.

Another military study that reported hours as well as costs (Wilkinson, 1983) illustrates a serious problem with the military studies. The costs of development and production for a single side of videodisc simulation were $18,700. The reported manhours, however, were 720 hours for programming, 180 hours for design and 480 hours for video production, for a total of 1380 hours. Even at a minimum commercial rate for these functions of $25, those hours represent a non-military cost of $34,500. It should also be noted that these military studies do not list content development time. The videodisc hardware costs in this study were $7,180 per system. Similar costs were reported by Edwards (1986) on a training program for a fuel savings advisory system for pilots. In this study a minimum of 320 hours were required to develop 2.5 hours of instruction on one videodisc side. No production costs were cited. Videodisc hardware cost $7,200 per system. Edwards (1986) also reported a potential cost savings of more than $8,000,000 over actual equipment training, if videodisc simulation were to be fully implemented.

In a study that only reported costs in dollars (Pieper et al., 1984), total investment for videodisc training was $653,400 versus $2,413,900 for actual equipment training. Ongoing expenses for the actual equipment training was projected at $247,200 yearly and $7,100 yearly for the videodisc simulation. In this study the development costs for the 29 maintenance simulations for videodisc was $300,000, and $250,000 was required to write the course support software.

These military cost studies, while important because of their manhour detail, are difficult to interpret because of the special, "in-house" conditions under which these simulations were created and by the nature of the simulations themselves. One Army study which was attempting to determine staffing standards for videodisc production noted that "a causal relationship does not exist between [instructional hours] and the hours it has taken to develop IVD [interactive videodisc] projects..." ("Manpower staffing", 1984, p. 2-20). This report goes on to cite one videodisc production that required 3,720 manhours for a single hour of instruction, while another production required only 4,048 manhours for 68 hours of instruction, or 59.5 development hours for each hour of instruction.

INDIVIDUAL PROGRAM COSTS

In civilian studies which report on the costs of videodisc production only, it is equally difficult to determine a dominant cost trend, particularly because of the limited information published. However, these cost data are helpful in setting some general parameters for videodisc development and production.

In the reports that list costs in dollars per videodisc, the range is between $66,000 and $150,000. Miller (1986b) lists the total costs at $400,000 or $66,000 per disc for an Annenberg/CPB project to create 6 videodiscs on science laboratory exercises. Digital Controls Video Group is producing 70 instructional hours of training on computer operation for a total cost of $2 million. The cost per disc is reported to be $100,000 ("SALT", 1985). There are several other reports of an "average" videodisc training package costing $100,000 per videodisc (Hoptman interview, 1987; Jonassen, 1984; Nugent interview, 1987; Smith, 1987). In addition, both Smith (1987) and Nugent (interview, 1987) report development and production costs of $3,000 to $5,000 per finished videodisc minute as another rough measure of costs.

Interactive Training Systems is producing 10 generic videodiscs to train 500,000 employees on health and safety at 194 manufacturing plants. The cost of the program is given as $1 million "plus", or just over $100,000 per disc ("Grapevine", 1987). A training program for aircraft mechanics developed at Federal Express also cost approximately $105,000 per disc in a combination of in-house and contract expenses, or about $30,000 per hour of delivered instruction (F. Rose, interview, July 21, 1987). At AT&T, a training class consisting of 4 videodisc sides was developed in 7 months, using 20 employees, and required the writing of 40,000 lines of computer code. The total cost is reported at $500,000 or $125,000 per disc ("The best", 1985). The Navy has developed several, single disc programs through a mix of outside contractors and in-house development for $150,000 per program (Miller, 1986a). Depending on the accounting methods used for in-house costs, some of those programs could have cost as much as $180,000 (P. Strube, interview, July 20, 1987). Magel (1986) also indicates a "typical" videodisc would cost $150,000, and reports costs for flowcharting and programming of $30 per hour to $1,500 per day.

There are several costing "worksheets" or "planning guides" available (Floyd, 1984; "Product description", 1985; Rebane, 1987; Roden, 1987). The cost-analysis worksheets by Roden (1987) appear to be the best suited to a training application, and have guidelines that have some resemblance to other data. Roden reports a range of $8,000 to $12,000 to develop an hour of lecture content, and suggests a conservative 25% time savings by students using videodisc training.

PROGRAM COST SAVINGS

As noted earlier in this report, the military are using videodisc simulation to save very large sums of money, because of the expense of their current actual equipment training. One study has noted a savings of $118.3 million in one course by substituting videodisc training for A.E.T. (Bernd, 1985). However, most of the savings in other training environments is realized by the reduced training time typically reported for students using videodisc training.

In the reviews of the literature, Smith (1987) found a 25%-50% reduction in time for videodisc training. Orlansky and String (1979, 1981) reported an average reduction of 30% for simulation training over actual equipment training. Balson et al., (1986) also reported a 30% reduction in training time using videodisc simulation. Strauss and Lentz (1987) conclude that individualized videodisc training generally takes 30%-35% less time to achieve the same results as forced-paced lecture methods.

Time savings cited in the available military studies range from 16% (Hull, 1984) to 56% (Hull, 1982) to 66% (Gibbons, Lines & Cavagnal, 1983). A study of a civilian flight simulator also reported a 66% time savings over conventional training (Miller & Baechtel, 1987). In the Florida training project for workers in the state AFDC program, the videodisc course reduced the training time from 160-200 hours for the lecture cycle to an average of 120 hours, or a minimum reduction of 25%. The fastest time through the videodisc training, 60 hours, represented a 63% reduction in training time (Smith, 1984). In this situation, videodisc training reduced the time required by students, and reduced instructor time to answering questions only. Consequently, the total training costs for this course were lowered from $44 per student to $.58 per student (Binder & Miller, 1986).

COSTS OF AUTOMOTIVE TRAINING

Of the published material on videodisc training only two reports contain information on the costs of videodiscs in the automotive industry. Chrysler, in conjunction with the United Auto Workers, recently developed a videodisc program on safety procedures for hazardous waste (Miller, 1987). The traditional lecture method for training workers on this topic required 2.5 hours for each of 85,000 workers, for a total of $4.25 million in lost wages. The salaries for 31 trainers and funds for course development were an additional $2.17 million. The videodisc training took an average of 36 minutes, with a range of 28-56 minutes. The training program itself cost $200,000 to develop, and required $2.25 million for approximately 150-200 videodisc systems. The total cost of the videodisc training was reported at $3.4 million, a savings of slightly more than $3 million.

In the effectiveness tests conducted by Ford Motor Company on their advanced videodisc training (Short, undated; Short & Croke, 1986), mechanics were able to complete what was reported as the equivalent of an 8 hour lecture course in only 59.9 minutes using videodisc. The range to complete the training was 41.1 minutes to 80.8 minutes. This report estimated that lecture training classes would cost Ford at least $11.87 million in 1989. The same courses on videodisc would cost only $5.67 million, a savings of $6.2 million. However, it appears that this report was prepared by the company that developed and produced the videodiscs and that conducted the evaluations of those videodiscs. Consequently there is some reason to question the objectivity of these findings.

What emerges from these widely varying reports are two tentative conclusions about the costs of videodisc training. First of all, videodisc technology is a relatively new training and educational tool and has found its first home in industrial and military training. Consequently, the reporting of costs suffers from the closed competitiveness of commercial enterprises and from the unique circumstances of the military environment. The second conclusion is that the extensive potential training features of videodisc delivery create an extremely wide range of actual training videodisc programs, from the very simple to the very complex. That range of possibilities makes the creation of cost and budget "rules of the thumb" very difficult. This problem of accurate budget forecasting has caused the military to adopt a complex formula based on the number of videodisc "frames", either still or motion, as a unit of content. In addition, the formula requires a detailed analysis of the level of interactivity of the instruction, and a breakdown of the number of graphics, still photographs, motion sequences, etc. The military is able to use this kind of a formula because they usually have a very detailed and extensive grasp of the content to be taught.

CONCLUSIONS

Computer-controlled videodiscs can be effective in delivering maintenance training and simulation. Videodiscs are generally less expensive to acquire than actual equipment trainers or 3-D simulators, but more expensive than computer-based instruction alone. However, videodisc training provides opportunities for equipment simulation not available with computer-based instruction. Videodiscs are the least expensive delivery method because of the elimination of instructors and the reduced training time required to complete coursework. These conclusions are confirmed by the reviews of literature that discuss cost-effectiveness issues (Azia, 1986; Bosco, 1986; Russ-Eft, 1985; Orlansky & String, 1979, 1981; Spuck, 1981; Van der Drift, 1981; Wilkinson, 1980) Videodiscs therefore provide the most cost-effective delivery method for hands-on mechanic training and verification testing.

However, throughout this study, the training tasks reviewed all focused on communicating a well-known body of knowledge, upon which most experts had agreed, about a particular and specific piece of equipment or set of procedures to a generally homogeneous and known audience. This is not the training task required of B.A.R. Rather, they are faced with the task of communicating an emerging and developing body of knowledge, upon which there is no general agreement, about a wide range of equipment and a variety of procedures to an audience that varies greatly in age, aptitude, ability and experience. In addition, this training task must be performed with limited manpower, facilities, equipment and financial resources.

As noted in a recent report on automobile mechanic training and certification in Hawaii (Allen, 1984), the "traditional mechanic is fading into American history as high-tech automobiles force [them] to learn more and become technicians" (p.7). This study also notes that what they refer to as an advanced auto mechanic should have a minimum of 540 hours of instruction. Among the recommendations of this study was a request that "curriculum content identification and validation surveys of the automotive service industry" be conducted to determine the recent technical innovations in the field (Allen, 1984).

A similar kind of standards-setting activity was completed in 1985 by the National Institute for Automotive Service Excellence (ASE), the National Automotive Technical Assistance Foundation and the Motor Vehicles Manufacturers Association (Shoemaker, 1985). These organizations spent $400,000 in developing the standards for certifying auto technician training programs at high schools and colleges.

Consequently, it is the conclusion of this investigation that the best application of the talents and resources available to B.A.R. would be in the development of standards of performance for mechanics. Those standards would then guide both public and private educational institutions in developing and delivering the coursework and training to meet those performance standards. The Bureau would oversee those institutions and their instruction to insure quality. In addition, B.A.R. should continue in its quality control function by creating a comprehensive examination procedure to verify the attainment of those standards of performance. That examination should be a videodisc-based, vehicle simulation test that will enable the Bureau to verify mechanics' ability to operate in the vehicle environment.

COST ANALYSIS OF TRAINING MODELS

The cost models described below are only five of an almost unlimited number of permutations and combinations of training designs and delivery systems. However, these models represent a range of options that address the original problem presented in B.A.R.'s solicitation, that is, to recommend "the most cost-effective approach for conducting hands-on training, retraining and testing." While this study will conclude with specific recommendations for Bureau action, this range of models is presented to give the Bureau a set of data upon which to draw as their needs dictate.

In addition, it should be noted that the actual costs of implementation of any of these models will change in the coming years. In addition to the obvious inflation factors that can affect salary, equipment costs, etc., the increasing experience of the training industry with the relative new medium of interactive videodisc, and the refinement of new design and production tools such as computer authoring languages, will also tend to alter the costs of the models that using videodisc technology.

Also, there are several new optical delivery formats and systems currently being introduced, such as compact disc-interactive (CD-I), digital video interactive (DVI), compact disc-read only memory (CD-ROM), and others. While currently untried in training applications, these systems offer some potential advantages to available videodisc delivery. Because of the potential of these new systems, as well as the variety of videodiscs currently available, the variability of actual costs at the time of implementation and the complexity of the design and production of these models, the Bureau should seek expert advice at the time of their actual solicitation. That advice would consist of the writing of very detailed specifications of the work to be performed for B.A.R., evaluating the submitted proposals, and reviewing work-in-progress.

Finally, it should be noted that the base costs and all models assume a six year span of training. This is the life of the current training that provides the origin of base costs. Base costs and models 3-5 assume a 16 hour block for training and testing (2 days). Models 1 and 2 assume a minimum 500 item test, to be completed in no more than 8 hours (1 day) in the paper-and-pencil administration. For uniformity and simplification, cost categories are referred to by the line numbers found to the left of the cost charts, and the column letters at the top. Identical or analogous categories retain the same line numbers in each model. Unless otherwise noted below, all costs are computed using the data described in the base costs.

DESCRIPTION OF CURRENT OPERATIONS (BASE COSTS)

This shows the costs for the development of the content, the design of the instructional package, the production of the video and print materials, the construction and reliability testing of the examination, and the delivery to students of the current B.A.R. Smog Check training. That training consists of the original 8 hour Qualification course produced by Colorado State University, and the 8 hour Requalification course produced by the California State Polytechnic University at Pomona. The actual cost figures that are used for the various categories are based specifically on the creation of the recent Requalification course. This approach was taken because the detailed breakdown of costs was not available for the Colorado State University contract, because B.A.R. personnel are familiar with the process and results of the creation of the Requalification course, and because the author was completely familiar with the exact definitions and component costs of the Requalification course done by Cal Poly, Pomona. In addition, using the figures from the creation of the Requalification course for Base Costs provides a "reality check" for B.A.R. personnel in understanding and judging the costs of the Models.

This use of the Qualification/Requalification courses as the Base Costs also provides a benchmark for the amount of content to be included in the training. While whatever new training that B.A.R. decides to provide may contain more or less than the current course content, the 16-hour content figure was maintained to allow comparison between the various training and delivery Models.

The empty categories of the Base Costs are there to maintain the line numbering of categories throughout the Models.

All models also show an approximate cost to business in lost revenue, and to the individual in lost wages. These are for comparison purposes only, and are not meant to reflect any research into actual revenue or wages.

	A	B	C	D	E
1	BUDGET LINE ITEM	UNITS	COST	SUBTOTAL	TOTAL
2					
3	***COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)***				
4					
5	PROJECT MANAGEMENT	567	$40	$22,680.00	
6	CLERICAL SUPPORT	432	$14.50	$6,264.00	
7	INSTRUCTIONAL DEVELOPMENT (COURSE CONTENT)				
8	NUMBER OF HOURS OF INSTRUCTION	5.50			
9	CONTENT DEVELOPMENT COST PER HOUR OF INSTRUCTION		$5,059	$27,824.50	
10	INSTRUCTIONAL DESIGN	327	$25	$8,175.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)			$0.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES	60			
14	PRODUCTION COST PER MINUTE		$1,590	$95,374.80	
15	PRINT GRAPHICS			$16,661.00	
16	COMPUTER GRAPHICS			$0.00	
17	AUTHORING/PROGRAMMING			$0.00	
18	TEST DEVELOPMENT			$2,500.00	
19	COURSEWARE/TEST EVALUATION			$3,050.00	
20	REVISION			$0.00	
21	(ORIGINAL DEVELOPMENT CONTRACT)			$363,300.00	
22	MISC. (TRAVEL, MATERIALS, CONTINGENCY, ETC.)			$16,488.00	
23	**TOTAL**				$562,317.30
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$18.74
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	INSTRUCTOR SALARY/SCHEDULING COSTS ($812 PER CLASS)	1,500	$812	$1,218,000.00	
28	OFFICE/CLASSROOM RENTAL ($650.00 PER MO. * 19 SITES)	72	$12,350	$889,200.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	SPECIALIZED EQUIPMENT	0		$0.00	
31	PRINT DUPLICATION (MANUALS)	30,000	$4	$120,000.00	
32	MEDIA DUPLICATION	0	$0	$0.00	
33	TEST SCORING/ RESULTS (CLERICAL SUPPORT)	30,000	$6	$180,000.00	
34	**TOTAL**				$2,521,200.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$84.04

BASE COSTS

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE			$0.00	
41	EQUIPMENT			$0.00	
42	**TOTAL**				$0.00
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				$3,083,517.30
45	**TOTAL COST PER STUDENT**	30,000			$102.78
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 16 HRS. CLASS AND TEST)	30,000	$640	$19,200,000.00	$19,200,000.00
50	LOST WAGES (AT $12.00/HR. * 16 HRS. CLASS AND TEST)	30,000	$192	$5,760,000.00	$5,760,000.00

NOTES ON BASE COSTS

These base costs are derived from the costs associated with the production and delivery of the initial B.A.R. Smog Check Qualification course and the current Requalification course. Together both courses constitute a 16 hour block of training and testing.

Courseware:

In general, the costs indicated under "Courseware Production and Development (16hrs)" are the costs associated with the same budget categories used in the production of the B.A.R. Requalification course. These are specific, known costs completely familiar to the author.

Line 8B: 5.5 is the actual number of hours of new instructional content created for the Requalification course.

Line 9D: $27,825 is the actual cost to develop that content. These costs include the work of an instructional designer and several content experts.

Line 9C: $5,059 is the per instructional hour development cost upon which are based other development costs in later models. This is the result of dividing $27,825 by 5.5 hours, and includes both staff designer time and the consulting costs of subject matter experts.

Line 21D: $363,300 is the amount of the original contract for the Qualification course. This figure was supplied by B.A.R. and includes the costs of modules 6,7,8, and the technical assistance provided by Colorado State University. In addition, there was an undefined impact on the Qualification course from the development of the "54-Hour" course. The "54-Hour" course cost $142,320, an amount not included in the Base Costs.

Training Delivery:

The "Training Delivery" costs were computed from base data supplied by B.A.R. The costs of delivery are totals for training 30,000 mechanics over a six-year period.

Line 27B: The assumption of all the models is a population of 30,000. At an average class size of 20, 1500 classes are required to train.

Line 27C: Current labor required for the preparation of each class (8 hours) is $406. This includes 10 hours of instructor time at $33 and $76 for scheduling. Two classes are required to compete current requirements. Therefore the total labor rate to deliver training is $812.

Line 28B: Six years, the life of the training, equals 72 months.

Line 28C: The costs for classroom rental average $650. per site, per month. With 19 training sites, the monthly classroom rental is $12,350.

Line 31B,C: Four manuals, two each for the Qualification and Requalification courses are required at $1 each.

Line 33B,C: Two tests are now administered, requiring exam scoring and the generation of results at $3 for each mechanic on each test.

Participation Costs:

The "Participation Costs" are the estimated costs to the employer in lost revenues (Line 49), and to the mechanic in lost wages (Line 50), from participation in the 16 hours of training and testing. These estimates are not intended to represent research into the actual historic costs of the Smog Check program. Rather, these estimated figures are intended to illustrate the relative economic efficiency of the various models.

MODEL 1- STANDARDS AND TESTING

Model 1 shows the costs to the Bureau for the development of standards for automotive emissions testing and repair and for the testing of mechanics. Model 1 makes no provision for the delivery of training by the Bureau. The assumption is that the training will be delivered by outside groups to the specifications of the Bureau, and that the bureau will retain a comprehensive testing function. This model maintains a paper-and-pencil methodology for testing.

The costs of this model are for the detailed task analysis of what knowledge and skills are required to test and repair automobile emission controls. The estimate of the amount of content to be covered is based on the current "54-Hour" Clean Air Car course, plus an additional six hours of new material currently being added. The task analysis is a comprehensive listing of the tasks or procedures that are required to complete a particular job. The task list subdivides major jobs such as "perform a tune-up" into all the component steps, lists tools required and in the case of gauges or instruments, lists the steps in using those tools. In addition the task list would also specify the particular knowledge required to perform a task. This would include the methods of finding information, such as the steps in locating specifications in appropriate manuals and other reference material, or the safety precautions that may be required during some procedures. The final product would be a hierarchy of the complete set of knowledge, skills and abilities that a mechanic needs to test and repair the emissions systems on California automobiles.

This model also provides for the development of a comprehensive examination based on that task analysis. Rather than using the sampling method of testing, where only a small portion of the material to be learned is actually tested, comprehensive testing attempts to test a complete set of knowledge, skills and abilities. While the practical restrictions of time, the endurance of the individual to be tested, and the particular nature of the content make it impossible to literally test all the information that may be required to be an emissions mechanic, the idea of comprehensive testing is to approach those limits. Consequently, a full day of testing, with an examination of approximately 500 items, is proposed in this model.

B.A.R. would then publish the full task list, making it available to individual mechanics and to educational and training organizations that wished to offer classes in emissions controls. The Bureau would continue to set standards for the authorized schools who offer this training, and B.A.R. would continue to conduct certification examinations for mechanics, using the new, comprehensive test.

MODEL 1 - STANDARDS AND TESTING

	A	B	C	D	E
1	BUDGET LINE ITEM	UNITS	COST	SUBTOTAL	TOTAL
2					
3	*COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)*				
4					
5	PROJECT MANAGEMENT	450	$40	$18,000.00	
6	CLERICAL SUPPORT	350	$14.50	$5,075.00	
7	INSTRUCTIONAL DEVELOPMENT (TASK ANALYSIS)				
8	NUMBER OF HOURS OF INSTRUCTION	60			
9	TASK ANALYSIS COST PER HOUR OF INSTRUCTION		$3,250	$195,000.00	
10	INSTRUCTIONAL DESIGN			$0.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)			$0.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES				
14	PRODUCTION COST PER MINUTE			$0.00	
15	PRINT GRAPHICS			$0.00	
16	COMPUTER GRAPHICS			$0.00	
17	AUTHORING/PROGRAMMING			$0.00	
18	TEST DEVELOPMENT	500	$35	$17,500.00	
19	TEST EVALUATION	500	$45	$22,500.00	
20	REVISION (2.5% OF 5D-18D)			$5,312.50	
21	(ORIGINAL DEVELOPMENT CONTRACT)			$0.00	
22	MISC. (TRAVEL, CONTINGENCY, MATERIALS-10% OF 5D-21D)			$26,338.75	
23	**TOTAL**				$289,726.25
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$9.66
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	PROCTOR/SCHEDULING (8HRS*1500 CLASSES/1 HR-WK PER SITE)	17,928	$21	$376,488.00	
28	OFFICE/CLASSROOM RENTAL ($650.00 PER MO. * 19 SITES)	72	$12,350	$889,200.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	SPECIALIZED EQUIPMENT	0		$0.00	
31	PRINT DUPLICATION (STANDARDS LIST @ $1.00)	30,000	$1	$30,000.00	
32	MEDIA DUPLICATION			$0.00	
33	TEST SCORING/RESULTS (CLERICAL SUPPORT)	30,000	$3	$90,000.00	
34	**TOTAL**				$1,499,688.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$49.99

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE (5% OF 23E)			$14,486.31	
41	EQUIPMENT (5% OF 30D)			$0.00	
42	**TOTAL**				$14,486.31
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				$1,803,900.56
45	**TOTAL COST PER STUDENT**	30,000			$60.13
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 8HRS. TEST)	30,000	$320	$9,600,000.00	$9,600,000.00
50	LOST WAGES (AT $12.00/HR. * 8HRS. TEST)	30,000	$96	$2,880,000.00	$2,880,000.00

NOTES ON MODEL 1-STANDARDS AND TESTING

Courseware:

Lines 5,6: The number of hours estimated for management are slightly less than the Base Costs because the work of the task analysis and test development would be more focused. The primary product is the detailed task list and the examination, both of which are the result of intensive effort by a relatively small group of experts.

Lines 7-9: The estimates for the development of the task list would be slightly less per hour than for the full content development noted in the Base Costs. While the task list covers more material, the teaching methodologies and descriptive material is not as extensive. In addition, some economies of scale can be achieved in 60 hours, rather than the base cost 5.5 hours, of development. Since there was no other bench mark available, the number of hours of instruction (60) in an expanded "54-Hour" course was used to indicate the scope of the task analysis.

Line 18: The test development assumes a criterion-based examination that is comprehensive in its approach. For estimation purposes only, a 500 item test is proposed. However, that number of items may very by 100 items more or less, depending upon the final nature of the content to be tested, and the design and method of testing. A 500-item test could be completed in one day. The $35 is a per-test item cost, and includes researching, writing and revising each question, based upon the assumption that the test writer has a complete task list to be tested.

Line 19: The test evaluation includes the costs of recruiting a representative sample population, administering the examination to that sample, and the computer analysis and standardization of the test. The $45 is a total per-question cost.

Line 20: Based on the results of the test evaluation, the entire task analysis may face some revisions. Because of the way in which a task analysis should be conducted, the revision estimate of 2.5% is conservative. This same revision formula is used where appropriate in the other models.

Line 22: This formula of 10% of the work is used in all the models to estimate the less financially consequential areas.

Training Delivery:

Line 27: Even though no training is conducted in this model, the assumption is that B.A.R. would want a proctor overseeing at all times this paper-and-pencil test. At an average of 20 mechanics per testing class, the test would require 1500 administrations. A proctor would work each administration for eight hours, or 12,000 total. The model assumes an additional one hour per week at each of the 19 test sites during the six year span of testing, or an additional 5,928 hours of clerical time.

Line 28: This classroom rental cost remains the same as the Base Costs. (NOTE: If any one of a number of different schemes of test administration were used, savings would be possible in this category, as well as additional savings in the administrative personnel listed in Line 27.

One example of another testing scheme would be a monthly or quarterly administration of the test in very large groups at a few large centers around the state.)

Line 31: Instead of printing manuals, this model assumes the duplication and distribution of the task analysis or "standards list".

Line 33: Only one test is administered, so the total costs for exam scoring and the generation of results is $3 per mechanic.

Maintenance:

All the models assume a courseware update and maintenance cost not present in Base Costs. Those maintenance costs are computed as 5% for both courseware and hardware. The courseware total is taken from line 23E; the hardware total from line 30D.

MODEL 2-SIMULATION TESTING

Model 2 assumes the completion of all the work specified in Model 1, including the development of the comprehensive task analysis and the paper-and-pencil examination. Model 2 then adds to Model 1 the concept of "hands-on" simulation testing. Rather than testing with paper-and-pencil, simulation testing uses sophisticated videodisc technology, computers and television images to create a realistic automotive environment in which the mechanic must function.

As noted earlier in this document, a videodisc is an optical storage medium for television, photographic or graphic images. In addition, videodiscs can store audio, text and computer data. In addition, the two audio tracks on the disc, and the use of computer-generated text material, will support dual-language applications. The additional costs of dual-language production are not included in any of the models. Because of the physical construction of the disc, and for some technical reasons, videodiscs allow for the rapid access of any of the information on the disc. Good videodisc design also creates interactive situations which involve the user. The configuration of a videodisc player and a computer will allow updating of information through the less expensive modifications of computer text, rather than the more expensive modifications of the videodisc itself.

This use of the videodisc for testing allows for complex sequencing and recognition test items, individual pacing, and direct computer scoring. The videodisc and computer controls can create simulations of actual mechanical conditions which present both the visual and audio parts of the mechanical problem. This kind of "hands-on" testing would assist in insuring that the mechanics can function in a real-world environment of engine parts and noises, rather than only learning the answers to a paper-and-pencil test. The costs of this model reflect the standards and test expenses of Model 1, and add the cost of the actual simulation test videodisc. This model also reflects some of the cost savings of self-paced, individualized delivery. From the research and other literature surveyed, 25% would be an estimated average savings in time for videodisc delivery.

This model envisions a situation in which the mechanic would call the local B.A.R. office to schedule a time for the examination. Because of the self-paced nature of the examination, and the capabilities of the computer for exam security, the test would not have to be completed in one administration, but could be divided into sections that could be taken on different days. A total time limit of 1-2 weeks could be established for completion of the entire examination. After arriving at the appointed time the mechanic would actually take the test in a small room that would be partitioned into several individual work stations, each containing a videodisc system. Consequently, other mechanics could be engaged in various sections of the test at the same time. The test would begin with a short introduction on how to use the system and make responses. Because the videodisc systems could be linked to B.A.R. headquarters, the completed tests could be "instantly" scored and recorded at the headquarters, and the results immediately sent back to the local office so that a certificate could be issued at the time of successful completion.

MODEL 2 - SIMULATION TESTING

	A	B	C	D	E
1	**BUDGET LINE ITEM**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
2					
3	***COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)***				
4					
5	PROJECT MANAGEMENT	675	$40	$27,000.00	
6	CLERICAL SUPPORT	525	$14.50	$7,612.50	
7	INSTRUCTIONAL DEVELOPMENT (TASK ANALYSIS)				
8	NUMBER OF HOURS OF INSTRUCTION	60			
9	TASK ANALYSIS COST PER HOUR OF INSTRUCTION		$3,250	$195,000.00	
10	INSTRUCTIONAL DESIGN	60	$25	$1,500.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)	360	$35	$12,600.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES	90			
14	PRODUCTION COST PER MINUTE		$1,000	$90,000.00	
15	PRINT GRAPHICS			$0.00	
16	COMPUTER GRAPHICS	400	$30	$12,000.00	
17	AUTHORING/PROGRAMMING	800	$35	$28,000.00	
18	TEST DEVELOPMENT	500	$35	$17,500.00	
19	TEST EVALUATION	500	$45	$22,500.00	
20	REVISION			$8,915.00	
21	(ORIGINAL DEVELOPMENT CONTRACT)			$0.00	
22	MISC. (TRAVEL, CONTINGENCY, MATERIALS, ETC.)			$42,262.75	
23	**TOTAL**				$464,890.25
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$15.50
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	CLERICAL SCHEDULING (1HR./WK PER SITE)	5,928	$21	$124,488.00	
28	OFFICE/CLASSROOM RENTAL ($180.00 PER MO. * 19 SITES)	72	$3,420	$246,240.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	LEVEL III VIDEODISC EQUIP (5 PER SITE @ $5000.00)	19	$25,000	$475,000.00	
31	PRINT DUPLICATION (STANDARDS LIST @ $1.00)	30,000	$1	$30,000.00	
32	MEDIA DUPLICATION (2 DISCS PER SYSTEM + MASTERS @ $5,000)	190	$25	$14,750.00	
33	COMPUTER TEST SCORING/RESULTS	30,000	$0.05	$1,500.00	
34	**TOTAL**				$1,005,978.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$33.53

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE			$23,244.51	
41	EQUIPMENT			$23,750.00	
42	**TOTAL**				**$46,994.51**
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				**$1,517,862.76**
45	**TOTAL COST PER STUDENT**	30,000			$50.60
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 6 HRS. TEST)	30,000	$240	$7,200,000.00	$7,200,000.00
50	LOST WAGES (AT $12.00/HR. * 6 HRS. TEST)	30,000	$72	$2,160,000.00	$2,160,000.00

NOTES ON MODEL 2-SIMULATION TESTING

Courseware:

This model assumes all the courseware costs of the "Standards and Testing" Model 1. Because this model, Simulation Testing, focuses on the specialized delivery of testing, it requires the completion of Model 1.

Lines 5,6: Since the scope of the work has increased to include all of Model 1 and the production of a simulation test on videodisc, the management and clerical requirements increase. That increase is slightly under 50% of Base Costs in these categories. The test videodisc would be less involved in production, but more complex in mastering. The management costs of development are already included in this model.

Line 10: Because this is a test-only videodisc, the overall instructional design would be relatively simple compared to a training videodisc.

Line 11: Because of the simplicity of the general design, the detailed flowcharting required for the programmer would be relatively simple. However, the flowcharting process could well require up to an hour per question, depending upon the method of presentation of the question.

Line 13: While the test is not timed, and is completed at different rates by different individuals, it is estimated that the combined test material of stills, motion video, graphics and audio would take 3 videodisc sides or 90 videodisc minutes.

Line 14: The video production costs of this videodisc would be reduced over the Base Costs because some of the visual material for the questions could be done with still photography and/or computer graphics.

Line 16: The questions for the test, the responses on the videodisc to choices by the mechanics, the graphic overlays of arrows, etc. and the creation of original graphic frames averages close to one hour per question.

Line 17: Authoring/programming refers to the actual creation of the computer program that controls the presentation of the test, the recording of the scores, the tabulation of scores and the transmission of scores to a central computer. That work can easily averages 8-10 hours per finished minute.

Training Delivery:

Line 27: Because of security designed into the test, and because the test is self-paced, with individuals working as their time is available, no separate B.A.R. supervision would be necessary. B.A.R. could provide scheduling only.

Line 28: Since mechanics could schedule test time individually, a large classroom is not required. A room of approximately 180 sq. feet would be adequate to hold the 5 videodisc stations per site.

Line 30: The average of 5 videodisc players per site, or 95 total players distributed as needed state-wide, was arrived at as follows. The average test time would be 6 hours total for 30,000 mechanics, or 180,000 hours. If testing were available 7 hours per day, it would require 25,714 days to complete testing with one videodisc testing unit. With 95 testing units, testing would require 271 days. This means that, if necessary, testing all 30,000 mechanics could be completed within approximately one year. Based on current costs, it is estimated that a purchase of 95 computer-controlled videodiscs, with monitors and stands would cost about $5,000 per unit.

Line 32: The test would require 2 videodiscs for each testing unit, or 190 total discs. The mastering process for making this number of copies would be an additional one-time cost of $5,000 for each disc, or $10,000 total.

Line 33: Because the videodisc testing units could be directly connected to a central computer, the maximum cost estimate for exam scoring and the generation of results is estimated at $.05 per mechanic.

Participation Costs:

The videodisc delivery system results in a decreased time required to complete material. A conservative estimated average time savings is 25%. Consequently, the maximum completion time of 8 hours for the pencil-and-paper test could be reduced to 6 hours for videodisc delivery.

MODEL 3-INDIVIDUAL 16HR CLASS

Model 3 simply converts the content, including all existing videotaped material, of the current qualification/requalification courses into an individualized, self-paced format on videodisc. The purpose of this model is to illustrate the cost savings in delivery of training with videodisc technology. The new costs reflect the funds needed to put the current courses onto videodisc. The only "new" training material would be the conversion of the content currently delivered by the instructor in the discussion sections of the courses. Note that this model uses the current test, but converts that test directly to videodisc in order to save additional time in test delivery and scoring.

This model would function in the same general way as Model 2. Here the training could be divided into individual sections for completion within an overall time frame. The test scoring and results generation would also happen as described in Model 2. However, because the training and test material is essentially identical to the current qualification and requalification courses, the enhanced learning capabilities of the videodisc for simulation and student interaction are not being fully utilized.

MODEL 3 - INDIVIDUAL 16HR CLASS

	A	B	C	D	E
1	**BUDGET LINE ITEM**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
2					
3	***COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)***				
4					
5	PROJECT MANAGEMENT	275	$40	$11,000.00	
6	CLERICAL SUPPORT	275	$14.50	$3,987.50	
7	INSTRUCTIONAL DEVELOPMENT (COURSE CONTENT)				
8	NUMBER OF HOURS OF INSTRUCTION (FROM INSTRUCTORS)	5			
9	CONTENT DEVELOPMENT COST PER HOUR OF INSTRUCTION		$3,250	$16,250.00	
10	INSTRUCTIONAL DESIGN	100	$25	$2,500.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)	160	$35	$5,600.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES	0			
14	PRODUCTION COST PER MINUTE		$0	$0.00	
15	PRINT GRAPHICS			$0.00	
16	COMPUTER GRAPHICS	600	$30	$18,000.00	
17	AUTHORING/PROGRAMMING	1,200	$35	$42,000.00	
18	TEST DEVELOPMENT			$0.00	
19	COURSEWARE/TEST EVALUATION			$0.00	
20	REVISION			$0.00	
21	(ORIGINAL DEVELOPMENT CONTRACTS)			$562,317.00	
22	MISC. (TRAVEL, CONTINGENCY, MATERIALS, ETC.)			$9,933.75	
23	**TOTAL**				$671,588.25
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$22.39
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	CLERICAL SCHEDULING (1HR./WK PER SITE)	5,928	$21	$124,488.00	
28	OFFICE/CLASSROOM RENTAL ($180.00 PER MO. * 19 SITES)	72	$3,420	$246,240.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	LEVEL III VIDEODISC EQUIP (5 PER SITE @ $5000.00)	19	$25,000	$475,000.00	
31	PRINT DUPLICATION (MANUALS)	30,000	$4	$120,000.00	
32	MEDIA DUPLICATION (4 DISCS PER SYSTEM + MASTERS @ $5,000)	380	$25	$29,500.00	
33	COMPUTER TEST SCORING/RESULTS	30,000	$0.05	$1,500.00	
34	**TOTAL**				$1,110,728.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$37.02

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE			$33,579.41	
41	EQUIPMENT			$23,750.00	
42	**TOTAL**				$57,329.41
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				$1,839,645.66
45	**TOTAL COST PER STUDENT**	30,000			$61.32
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 12 HRS. CLASS AND TEST)	30,000	$480	$14,400,000.00	$14,400,000.00
50	LOST WAGES (AT $12.00/HR. * 12 HRS. CLASS AND TEST)	30,000	$144	$4,320,000.00	$4,320,000.00

NOTES ON MODEL 3-INDIVIDUAL 16 HOUR CLASS

Courseware:

Lines 5,6: Because this model concentrates on the conversion of existing material to a videodisc format, with very little creation of new content, managerial costs could be reduced about 50% from Base Costs.

Line 8: Approximately five hours of content currently delivered by instructors in the form of discussion and exercises would need to be standardized and designed for individual delivery. In addition, the material from the study guides and manuals would have to be integrated into this method of presentation.

Lines 10,11: The conversion of the existing material to a videodisc format would require more instructional design time than the simulation testing of Model 2. However, since this would be a conversion of existing material, and therefore have a relatively direct structure, this model would require a reduced amount of flowchart time.

Line 16: The new instructional content developed for this conversion would be textual material inserted as graphics. In addition the current test would be converted to computer text for delivery on this system.

Line 17: Because the original video material is at least 31/2 hours or 7 videodisc sides, it will require approximately twice as long to program as the three sides of the simulation testing discs of Model 2.

Line 21: This is the total cost of original production for the current qualification and requalification courses (Base Costs, line 23).

Training Delivery:

Lines 27-30: The delivery system of this model is the same as Model 2, requiring scheduling only, a reduced room, and the purchase of videodisc systems.

Line 31: This model assumes the use of the same manuals and study guides as the current courses described in Base Costs.

Line 32: The length of the current video material plus tests would require a minimum of 7 disc sides (4 videodiscs). Mastering costs would be $20,000 plus the 4 discs for each of 95 systems.

Line 33: Computer scoring costs would be the same as Model 2.

Participation Costs: This model assumes the same 25% reduction in completion time as Model 2.

MODEL 4-NEW 16HR CLASS

Model 4 creates an entirely new 16 hour, individualized, self-paced videodisc-based course from the task analysis standards and comprehensive testing discussed in Model 1. This model also incorporates *the simulation testing of Model 2 and the economies of delivery of Model* 3. In addition, this model uses the videodisc medium to include extensive visual and audio simulation of the actual kinds of problems encountered in smog testing, diagnosing malfunctions and performing repairs in the training as well as the testing.

This model would operate in the same fashion as Models 2 and 3. However, during the training portions, the mechanic would encounter detailed motion sequences, and/or still photographs with appropriate audio, of actual situations on a variety of automobiles. The mechanic could be required to correctly identify components, place components in the correct location within an emissions system, indicate what kinds of problems are present within a particular audiovisual display, correctly use instruments illustrated on the videodisc, perform particular mechanic repair operations in the correct sequence, and a wide range of similar kinds of operations that can closely simulate actual work conditions.

MODEL 4 - NEW 16HR CLASS

	A	B	C	D	E
1	BUDGET LINE ITEM	UNITS	COST	SUBTOTAL	TOTAL
2					
3	***COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)***				
4					
5	PROJECT MANAGEMENT	1,350	$40	$54,000.00	
6	CLERICAL SUPPORT	1,050	$14.50	$15,225.00	
7	INSTRUCTIONAL DEVELOPMENT (TASK ANALYSIS)				
8	NUMBER OF HOURS OF INSTRUCTION	60			
9	TASK ANALYSIS COST PER HOUR OF INSTRUCTION		$3,250	$195,000.00	
10	INSTRUCTIONAL DESIGN	240	$25	$6,000.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)	1,440	$35	$50,400.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES	330			
14	PRODUCTION COST PER MINUTE		$1,000	$330,000.00	
15	PRINT GRAPHICS			$0.00	
16	COMPUTER GRAPHICS	800	$30	$24,000.00	
17	AUTHORING/PROGRAMMING	2,400	$35	$84,000.00	
18	TEST DEVELOPMENT	500	$35	$17,500.00	
19	TEST EVALUATION	500	$45	$22,500.00	
20	REVISION			$17,672.50	
21	(ORIGINAL DEVELOPMENT CONTRACT)			$0.00	
22	MISC. (TRAVEL, CONTINGENCY, MATERIALS, ETC.)			$81,629.75	
23	**TOTAL**				$897,927.25
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$29.93
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	CLERICAL SCHEDULING (1HR./WK PER SITE)	5,928	$21	$124,488.00	
28	OFFICE/CLASSROOM RENTAL ($180.00 PER MO. * 19 SITES)	72	$3,420	$246,240.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	LEVEL III VIDEODISC EQUIP (5 PER SITE @ $5000.00)	19	$25,000	$475,000.00	
31	PRINT DUPLICATION (STANDARDS LIST @ $1.00)	30,000	$1	$30,000.00	
32	MEDIA DUPLICATION (6 DISCS PER SYSTEM + MASTERS @ $5,000)	570	$25	$44,250.00	
33	COMPUTER TEST SCORING/RESULTS	30,000	$0.05	$1,500.00	
34	**TOTAL**				$1,035,478.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$34.52

MODEL 4 - NEW 16HR CLASS

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE			$44,896.36	
41	EQUIPMENT			$23,750.00	
42	**TOTAL**				$68,646.36
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				$2,002,051.61
45	**TOTAL COST PER STUDENT**	30,000			$66.74
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 12 HRS. CLASS AND TEST)	30,000	$480	$14,400,000.00	$14,400,000.00
50	LOST WAGES (AT $12.00/HR. * 12 HRS. CLASS AND TEST)	30,000	$144	$4,320,000.00	$4,320,000.00

NOTES ON MODEL 4-NEW 16 HOUR CLASS

Courseware:

This model assumes the work of Models 1 and 2.

Lines 5,6: This model requires approximately 5 times the amount of video production as the Base Costs and the increased complexity of training videodiscs. Management and clerical support reflect this increase workload.

Line 8: The task analysis from Model 1 assumes 60 hours of instruction. It should be noted here that Model 4 assumes actually training only the 16 hours that is analogous to the current content of the qualification/requalification courses. This is necessary to keep the models as equivalent and therefore as comparable as possible.

Lines 10,11: The assumption of this model calls for the production of a series of complex and intricate training videodiscs. Consequently the design will require at least 40 hours per videodisc, and the flowcharts 240 hours per videodisc.

Lines 13,14: While this model assumes 12 videodisc sides (6 discs), the equivalent of 1 side, or 30 minutes, would be graphics. Consequently, only 5.5 hours, or 330 minutes, would be video and still photographic production.

Line 16: In addition to the 400 hours of computer graphics necessary for the development of the test (Model 2), it is estimated that an addition 400 hours of computer graphics would be required for overlays and other textual material.

Line 17: Even though this is a more complex task, the programming time is based on the estimates of Model 2 for 400 hours of programming per disc. The assumption is that some economies of scale will apply in this longer programming task, and offset the increased complexity.

Training Delivery:

The delivery costs of this model are approximately the same as Model 2. The slight increase in this model's costs are reflected in **Line 32,** which lists the additional number of discs required over Model 2.

MODEL 5-16HR HANDS-ON CLASS

Model 5 illustrates the costs for a 16 hour class using actual, full hands-on automobile engines, equipped with complete emission devices and connected to computers for control. This model assumes all the work of Model 1 in creating the task analysis standards list and comprehensive test. In addition, the actual training materials, including specialized mechanical exercises for the students, would need to be created. A computer program to control some of the malfunction simulations, to provide continuing feedback to the mechanics on their performance, and to deliver the final testing, would also be required. The high costs associated with this model are primarily devoted to hardware creation and acquisition and to increased time required to deliver the training.

This model assumes that the training will be delivered in a group. This group delivery is required because of the need to set-up the mechanical components of the engine between individual exercises, for demonstrations, for safety, and for oversight during the work on the engines. The mechanics would each be assigned to a full engine simulator. During the training, they would be required to test, diagnose and repair emissions components on those engines in a series of separate exercises. The final examination would be delivered by the computer and scored as in Model 2.

MODEL 5 - 16HR HANDS-ON CLASS

	A	B	C	D	E
1	**BUDGET LINE ITEM**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
2					
3	***COURSEWARE PRODUCTION AND DEVELOPMENT (16HRS)***				
4					
5	PROJECT MANAGEMENT	900	$40	$36,000.00	
6	CLERICAL SUPPORT	700	$14.50	$10,150.00	
7	INSTRUCTIONAL DEVELOPMENT (TASK ANALYSIS)				
8	NUMBER OF HOURS OF INSTRUCTION	60			
9	TASK ANALYSIS COST PER HOUR OF INSTRUCTION		$3,250	$195,000.00	
10	INSTRUCTIONAL DESIGN	180	$25	$4,500.00	
11	SPECIFIC COURSE DESIGN (INCLUDING DETAILED CBI FLOWCHART)	1,040	$35	$36,400.00	
12	PRODUCTION (AUDIO/VIDEO/STILL)				
13	NUMBER OF FINISHED MINUTES	0			
14	PRODUCTION COST PER MINUTE		$0	$0.00	
15	PRINT GRAPHICS			$0.00	
16	COMPUTER GRAPHICS	1,200	$30	$36,000.00	
17	AUTHORING/PROGRAMMING	1,600	$35	$56,000.00	
18	TEST DEVELOPMENT	500	$35	$17,500.00	
19	TEST EVALUATION	500	$45	$22,500.00	
20	REVISION			$8,635.00	
21	(ORIGINAL DEVELOPMENT CONTRACT)			$0.00	
22	MISC. (TRAVEL, CONTINGENCY, MATERIALS, ETC.)			$42,268.50	
23	**TOTAL**				$464,953.50
24	**COST PER STUDENT FOR PRODUCTION**	30,000			$15.50
25	***TRAINING DELIVERY (SIX YEARS)***				
26					
27	INSTR. SALARY ($33*18HRS CLASS+16HRS PREP)/SCHED ($76)	3,000	$1,198	$3,594,000.00	
28	OFFICE/CLASSROOM RENTAL ($1,300 PER MO. * 19 SITES)	72	$24,700	$1,778,400.00	
29	EQUIPMENT (OFFICE, VIDEO PLAYBACK, ETC. $6,000.00/SITE)	19	$6,000	$114,000.00	
30	COMPUTERIZED, OPERATING, GAS ENGINE SIMULATORS @ $20K	190	$20,000	$3,800,000.00	
31	PRINT DUPLICATION (STANDARDS LIST AND MANUALS)	30,000	$3	$90,000.00	
32	MEDIA DUPLICATION	0	$0	$0.00	
33	COMPUTER TEST SCORING/RESULTS	30,000	$0.05	$1,500.00	
34	**TOTAL**				$9,377,900.00
35	**COST PER STUDENT FOR DELIVERY**	30,000			$312.60

MODEL 5 - 16HR HANDS-ON CLASS

	A	B	C	D	E
36	**BUDGET LINE ITEM (ASSUMES 30,000 STUDENTS)**	**UNITS**	**COST**	**SUBTOTAL**	**TOTAL**
37					
38	***MAINTENANCE COST***				
39					
40	COURSEWARE			$23,247.68	
41	EQUIPMENT			$190,000.00	
42	**TOTAL**				$213,247.68
43					
44	**TOTAL COST TO BAR TO DELIVER TRAINING/TESTING**				$10,056,101.18
45	**TOTAL COST PER STUDENT**	30,000			$335.20
46					
47	***PARTICIPATION COST***				
48					
49	LOST REVENUE (AT $40.00/HR. * 16 HRS. CLASS AND TEST)	30,000	$640	$19,200,000.00	$19,200,000.00
50	LOST WAGES (AT $12.00/HR. * 16 HRS. CLASS AND TEST)	30,000	$192	$5,760,000.00	$5,760,000.00

NOTES ON MODEL 5-16 HOUR "HANDS-ON" CLASS

Courseware:

This model assumes the work of Model 1.

Lines 5,6: Management and clerical support reflect the increased workload over Model 1 of the creation and programming of the "hands-on" hardware simulator.

Line 8: The task analysis from Model 1 assumes 60 hours of instruction. It should be noted here that Model 5 assumes actually training only the 16 hours that is analogous to the current content of the qualification/requalification courses. This is necessary to keep the models as equivalent and therefore as comparable as possible.

Lines 10,11,17: These are general, conservative estimates of the time required to design, flowchart and actually create the computer program necessary to operate the simulator, track student results, and administer the examination.

Line 16: The assumption of this model is that a computer screen will provide some directions and feedback to students as they work through exercises, and administer the examination. This time reflects the estimate to create those computer graphics.

Training Delivery:

Line 27B: This model assumes a reduction in class size from the average of 20 used in the Base Costs and Model 1, to 10 in this model. This permits one mechanic per simulator. Because of the costs of the simulators, the potential labor savings of larger classes are offset by increased capital and maintenance costs. Consequently, this model assumes 3,000 classes to train and test 30,000 mechanics.

Line 27C: This model would require the presence of an instructor during class to assist in delivering training (16 hours). In addition, the mechanical elements of the simulator would require 2 more days (16 hours) to reconfigure and prepare each simulator for the next class (10 simulators per site, 1.6 hours per simulator). An additional 2 hours per class of instructor training and preparation and $76 for scheduling (from the base costs) are included. Exams would be computer scored.

Line 28: It is estimated that 10 simulators would require twice the current space. While special modifications to the space may be required, depending on the actual size and configuration of the simulators, there was no method to estimate those unknowns.

Line 30: The simulators, consisting of a gasoline engine with complete smog controls and custom attachments for the major engine manufacturers and engine configurations, plus interconnected computer hardware and display screens, could not be constructed for less than $20,000 each.

Line 31: The assumption is that some manuals, such as Smog Check, would be required in this model, as well as the printing of the standards list from Model 1.

MODEL COSTS SUMMARY

This summary statement lists the total cost to B.A.R. for the production and delivery of training, taken from line 44E of the Base Costs and each of the Models. The costs per student and the participation costs are then listed for each Model, taken from the appropriate lines of each cost chart. Since the origins of the costs summarized here were explained in each Model, there are no NOTES with this chart.

MODEL COSTS SUMMARY

	A	B
1	***BASE COSTS***	
2		
3	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$3,083,517.30**
4	COST PER STUDENT - PRODUCTION	**$18.74**
5	COST PER STUDENT - DELIVERY	**$84.04**
6	TOTAL COST PER STUDENT	**$102.78**
7		
8	PARTICIPATION COST	
9		
10	LOST REVENUE (AT $40.00/HR. * 16 HRS. CLASS AND TEST)	**$19,200,000.00**
11	LOST WAGES (AT $12.00/HR. * 16 HRS. CLASS AND TEST)	**$5,760,000.00**
12		
13	***MODEL 1 - STANDARDS AND TESTING***	
14		
15	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$1,803,900.56**
16	COST PER STUDENT - PRODUCTION	**$9.66**
17	COST PER STUDENT - DELIVERY	**$49.99**
18	TOTAL COST PER STUDENT	**$60.13**
19		
20	PARTICIPATION COST	
21		
22	LOST REVENUE (AT $40.00/HR. * 8HRS. TEST)	**$9,600,000.00**
23	LOST WAGES (AT $12.00/HR. * 8HRS. TEST)	**$2,880,000.00**
24		
25	***MODEL 2 - SIMULATION TESTING***	
26		
27	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$1,517,862.76**
28	COST PER STUDENT - PRODUCTION	**$15.50**
29	COST PER STUDENT - DELIVERY	**$33.53**
30	TOTAL COST PER STUDENT	**$50.60**
31		
32	PARTICIPATION COST	
33		
34	LOST REVENUE (AT $40.00/HR. * 6 HRS. TEST)	**$7,200,000.00**
35	LOST WAGES (AT $12.00/HR. * 6 HRS. TEST)	**$2,160,000.00**
36		
37	***MODEL 3 - INDIVIDUAL 16HR CLASS***	
38		
39	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$1,839,645.66**
40	COST PER STUDENT - PRODUCTION	**$22.39**
41	COST PER STUDENT - DELIVERY	**$37.02**
42	TOTAL COST PER STUDENT	**$61.32**
43		
44	PARTICIPATION COST	
45		
46	LOST REVENUE (AT $40.00/HR. * 12 HRS. CLASS AND TEST)	**$14,400,000.00**
47	LOST WAGES (AT $12.00/HR. * 12 HRS. CLASS AND TEST)	**$4,320,000.00**

MODEL COSTS SUMMARY

	A	B
48	***MODEL 4 - NEW 16HR CLASS***	
49		
50	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$2,002,051.61**
51	COST PER STUDENT - PRODUCTION	**$29.93**
52	COST PER STUDENT - DELIVERY	**$34.52**
53	TOTAL COST PER STUDENT	**$66.74**
54		
55	PARTICIPATION COST	
56		
57	LOST REVENUE (AT $40.00/HR. * 12 HRS. CLASS AND TEST)	**$14,400,000.00**
58	LOST WAGES (AT $12.00/HR. * 12 HRS. CLASS AND TEST)	**$4,320,000.00**
59		
60	***MODEL 5 - 16 HR HANDS-ON CLASS***	
61		
62	TOTAL COST TO BAR TO DELIVER TRAINING/TESTING	**$10,056,101.18**
63	COST PER STUDENT - PRODUCTION	**$15.50**
64	COST PER STUDENT - DELIVERY	**$312.60**
65	TOTAL COST PER STUDENT	**$335.20**
66		
67	PARTICIPATION COST	
68		
69	LOST REVENUE (AT $40.00/HR. * 16 HRS. CLASS AND TEST)	**$19,200,000.00**
70	LOST WAGES (AT $12.00/HR. * 16 HRS. CLASS AND TEST)	**$5,760,000.00**

RECOMMENDATIONS

1. *B.A.R. should no longer actually conduct mechanic training, but should continue to test, certify and license.*

Because of the ever-increasing complexity of emission systems in particular, and automobiles in general, the Bureau should concentrate its resources on setting quality and performance standards for both the public and private institutions whose business it is to train and educate. These standards should include task lists of the knowledge, skills and abilities required by qualified mechanics to test, diagnose and repair emissions systems and the standards for instructors delivering training at public and private institutions. In addition, the Bureau should approve proposed course plans, facilities and lists of available equipment submitted by institutions interested in offering mechanic training.

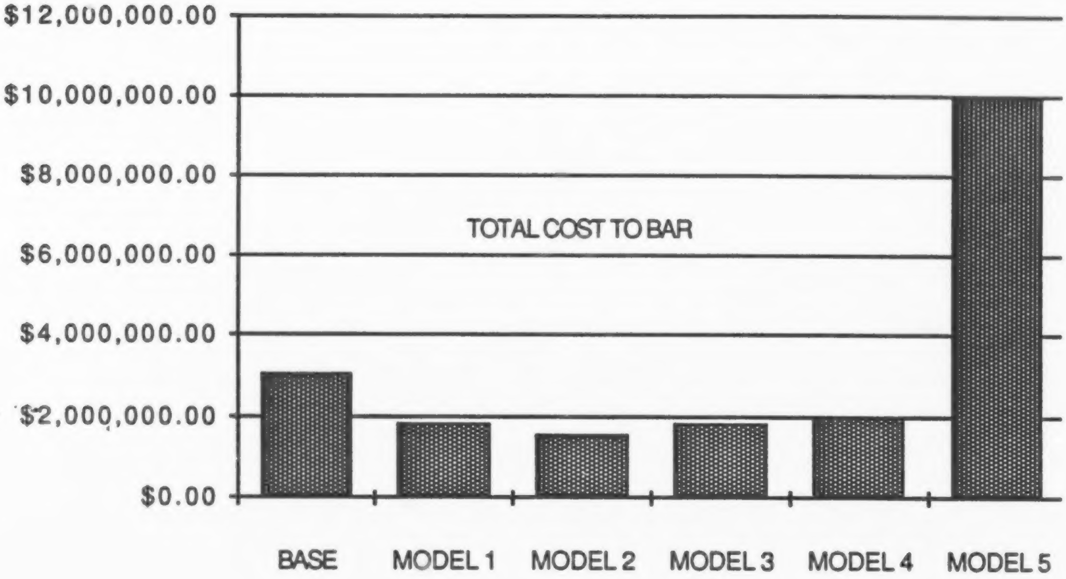
If the Bureau has an actual training role, it should confine training to the rules and regulations that govern the state programs it administers. Since that specific situation was not part of the charge of this study, no specific models of this kind of training were developed. However, some of the costs and delivery methods associated with Models 2 and 4 would assist B.A.R. in exploring this option.

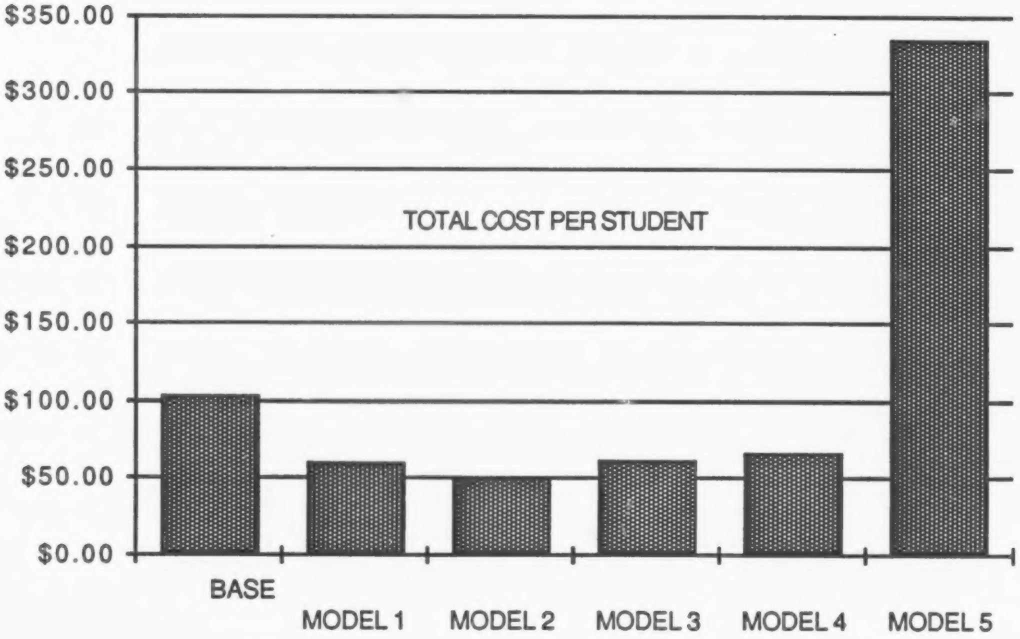
2. *B.A.R. should test, certify and license mechanics through comprehensive "hands-on" simulation testing.*

While removing itself from the delivery of training, the Bureau should maintain control over the quality of mechanics through the use of the testing, certification and licensing function. That testing function should be upgraded to a form of comprehensive examination, analogous to the Board examinations conducted for professionals in nursing, physical therapy, real estate, law, medicine, et cetera. In addition, this comprehensive testing for mechanics should be conducted by a method that helps to insure mechanics are able to perform in the vehicle environment and not simply on a written test.

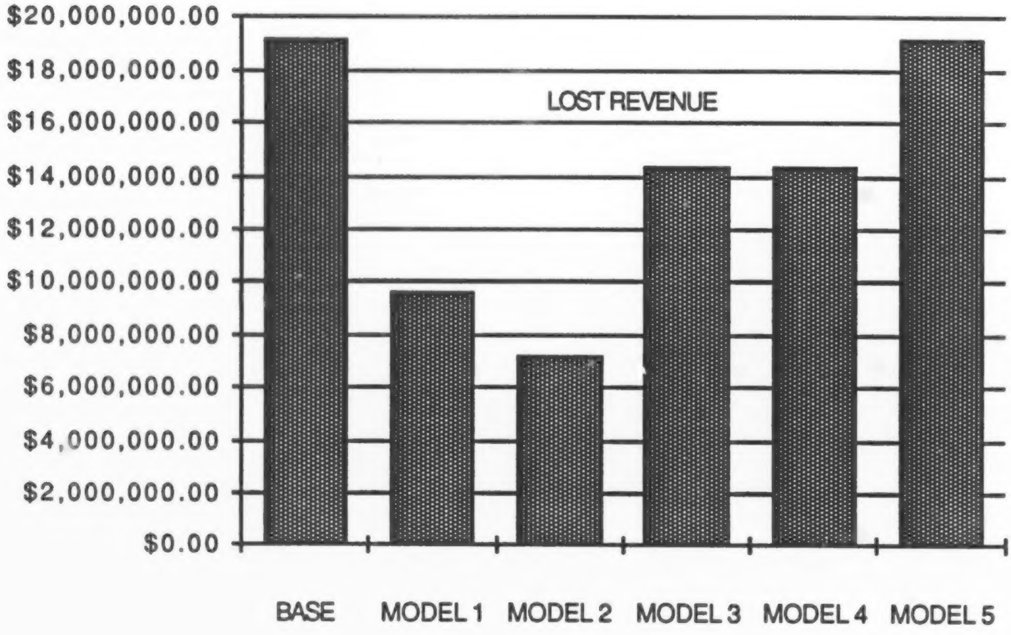
Model 1, "Standards and Testing", satisfies the need for standards setting and comprehensive testing. It is also very cost effective. However, this model fails to address the problem of insuring performance in a realistic environment.

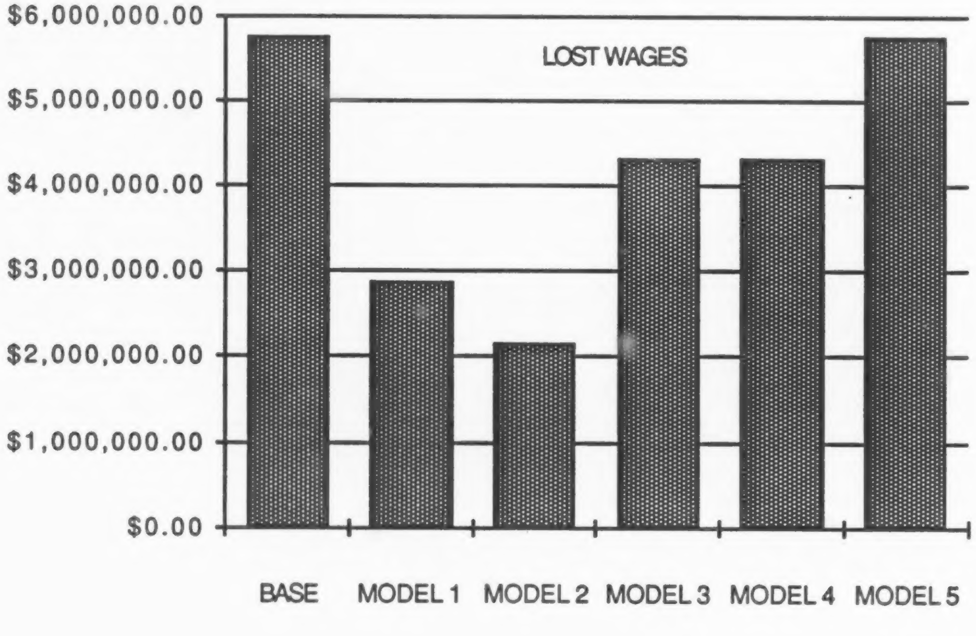
Model 2, "Simulation Testing", offers the advantages of standards setting, comprehensive testing and some insurance that mechanics can perform in a realistic environment. Because of the economies of delivery, this is the most cost-effective model as noted in following charts comparing the total costs of all the models and the total costs per student.





In addition, this model has the least economic impact on mechanics and their employers, as noted in the following charts comparing the lost revenue and the lost wages of the various models.


$20,000,000.00
$18,000,000.00
$16,000,000.00
$14,000,000.00
$12,000,000.00
$10,000,000.00
$8,000,000.00
$6,000,000.00
$4,000,000.00
$2,000,000.00
$0.00
LOST REVENUE
BASE
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5


$6,000,000.00
$5,000,000.00
$4,000,000.00
$3,000,000.00
$2,000,000.00
$1,000,000.00
$0.00
LOST WAGES
BASE
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5

Model 3, "Individual 16HR Class", still has the Bureau training mechanics. In addition, this model offers few of the learning or testing enhancements of other models. It is more cost-effective than current Bureau training operations.

Model 4, "New 16HR Class", still has the Bureau training mechanics. However, this is completely new training based on a set of standards, and provides comprehensive, "hands-on" simulation testing. It is more expensive than three of the other models, but is less costly for mechanics and their employers than the current training.

Model 5, "16HR Hands-On Class" still has the Bureau training mechanics. However, this model does provide actual hands-on training and testing of mechanics. It is very expensive to deliver, and is as expensive for mechanics and their employers as the current classes.

Therefore, this study recommends Model 2, "Simulation Testing", as being the most effective method of insuring a hands-on, quality control capability for B.A.R., provided in the most cost-efficient manner.

As noted earlier in this study, the potential of new optical delivery systems, the variety of videodisc systems currently available, the variability of actual costs at the time of implementation and the complexity of the design and production of these models, all indicate that the Bureau should seek expert advice at the time of their actual solicitation. That advice would consist of the writing of very detailed specifications of the work to be performed for B.A.R., evaluating the submitted proposals, and reviewing work-in-progress.

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APPENDIX A

INTERVIEWS, CONFERENCES AND SITE VISITS

INTERVIEWS

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Strube, Philip. Naval Health Sciences Education and Training Command, Bethesda, MD. Interviewed in Monterey, CA., July 20, 1987.

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SITE VISITS AND CONFERENCES

Citrus Motors (Ford dealership). 835 W. Holt Blvd, Ontario, CA.

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APPENDIX B

TELEVISION-CENTERED, INSTRUCTIONAL DELIVERY SYSTEMS: COSTS AND CASE STUDIES

A Review of Research

THOMAS G. MAHER
June 1, 1982

INTRODUCTION

Educational television has come to play a major role in higher education in America. The recent figures from a study done by the National Center for Educational Statistics and the Corporation for Public Broadcasting show that 71% of the institutions of higher education in the United States use television in some capacity (Dirr et al., 1981). However, this burgeoning use of television for instruction raises some important questions for educational planners and decision-makers. In a presentation to the annual meeting of the American Educational Research Association, Richardson (1981) outlines several areas in television-centered delivery systems that require exploration. One of these is the need for a review of research on the capacities, logistics and costs of the various delivery technologies, and on the case studies of their respective operations, particularly in relationship to adult learners.

This paper attempts to address that need. Because costs of television systems are greatly influenced by advances in the technology, this review is limited to research published after 1975. In addition, this is not meant to be an inclusive survey. Early studies summarized in later work are omitted. This review also concentrates on television systems in the United States. International projects have created massive amounts of valuable raw data, but the particular and often unique circumstances of each international effort limit their value in American applications. A comprehensive listing of these projects can be found in Young et al. (1980, pp. 162-233). Finally, only those case studies concerning higher and postsecondary, continuing and adult education, and which contain actual rather than projected cost data, have been included.

This paper begins with a section on the general definitions and capacities of various delivery technologies. The next section describes cost methods and model systems, and includes a discussion of the general cost of telecourse program production, which can be a constant, recurring factor regardless of delivery system. A review of case studies of the individual technologies is presented next, followed by a separate discussion of those studies that use a mix of television delivery systems. A final section suggests directions for future research. The systems that are examined are the broadcast technologies of open broadcasting, instructional television fixed service (ITFS), and satellites; cable distribution, both one direction and interactive; and the copy systems of open reel and cassette videotape and videodiscs.

Although Richardson (1981) is interested in the way these delivery systems can be used to meet the particular needs of adult learners in distance learning situations, very few of the reports make those connections. Consequently, this review has included studies that provide basic system information, but which may require the reader to apply the system to adults.

GENERAL DEFINITIONS AND CAPACITIES

All the television-centered delivery systems offer education two basic services. First, they enhance instruction by adding information such as interviews with experts, particular demonstrations or exposure to locations and events that cannot be adequately conveyed by the written or spoken word. Secondly, they can greatly expand the audience for instruction (Munshi, 1980a). However, each system has its own requirements and peculiarities.

Dordick, Bardley & Fleck (1979) divide the television-centered delivery systems into three broad groups: over-the-air transmissions, cable distribution and copy technologies. Over-the-air transmissions, consisting of broadcasting, Instructional Television Fixed Service (ITFS) and satellite relays, are broadly defined as the modulation of electro-magnetic radiation, in line-of-sight transmissions, that diminish over distance. These systems are also direct delivery technologies: materials must be used at the time of transmission. Broadcasting uses signals that only require a standard television to receive, while ITFS and satellite relays need special reception equipment at each site that is expensive ($10,000-$30,000). Although broadcasting reaches 60-75% of all schools and is relatively low cost when used with a large number of receivers, and for each additional student, these advantages for education are offset by several problems, such as limited appropriate programming and schedule problems caused by single channel direct delivery. ITFS and satellite relays remove these disadvantages because they are capable of multi-channel distribution. They also have two-way audio capability. While ITFS is limited to a range of 25 miles, a satellite can distribute over an area, called a footprint, of hundreds of thousands of square miles and also has two-way video capability.

Cable distribution systems are defined by Dordick et al. (1979) as electro-magnetic transmissions, through wire or optical fibre cables, to fixed locations. These signals can be regenerated along the cable and are unaffected by typography, so they can theoretically cover greater distances than some over-the-air transmissions. While cable systems require tremendous capital costs for installation, they have a high quality signal, often have interactive, two-way audio and video capability and can offer programming flexibility because of their multi-channel capacity (12-108 channels).

The copy technologies of videotape, both open reel and cassette, and videodisc, are physical delivery systems, rather than electro-magnetic transmissions. The program information is electronically recorded on the magnetic coating of videotape, in the grooves of capacitance videodiscs or in laser images on optical videodiscs. Videotape offers both recording and playback capabilities and, in helical format videotape, stop-motion. Videodiscs, while capable of playback only, offer complete stop motion, slow motion and rapid random access to any portion of the disc program. Videodiscs currently suffer from a lack of technical standardization and availability of programming. All the copy technologies require physical transportation to the instructional site and the costs of administering the distribution may be greater than the individual system hardware. However, copy technologies offer great flexibility and are an inexpensive way to start a television-centered delivery system.

Analysis of the strengths and weaknesses of these delivery systems (Instructional Television: A Comparative Study, 1976) concluded that broadcasting was the best choice in high density population areas. Satellite delivery was judged to be the most effective with remote populations distributed over large areas and when broadcasting several hours of programming. Cable was the cost-effective choice for multi-channel distribution, if the cable was already in place. However, this study found ITFS was cheaper if a new delivery system had to bear the high cost of cable installation. In situations that required scheduling flexibility, program choice and variety, videotape on cassettes was the preferred choice. Similar conclusions were reached by Graff (1980) and Shulman (1981). Haque (1978) and Curtis (1979) provide useful summary charts of the capabilities of each technology.

However, these reports do not relate the use of television-centered delivery systems to a particular audience, let alone to the needs of adult learners. Luskin (1980) makes a brief and general reference to the capacity of these delivery systems to expand the "campus" of higher education. Baltzer (1980, 1981), while not providing any definitive answers, asks some central questions about television-centered, as well as other alternative delivery systems and their relationship to the adult learner. These questions are concerned with the nature of the intended audience, the requirements of course content, the cost-effectiveness of each system and the availability of appropriate programming. Once these questions are answered, the best system, or mix of systems, can then be chosen (Baltzer, 1981).

COST METHODS AND MODEL SYSTEMS

COST METHODS

At first blush, determining the costs of televised instruction would seem a fairly straightforward task. However, as Schramm et al., noted as late as 1967, in The New Media: Memo to Educational Planners,

> It is necessary to admit with regret...that we simply do not have available at present the necessary data with which to treat in any very sophisticated way the comparative educational efficiency of the new media in terms of cost....In the next five or ten years, let us hope, much better data and measures will be available. (pp. 122-123)

While the actual costs and case studies summarized by Schramm et al. (1967) are both outdated and outside the higher education focus of this review, the problems encountered in this cost study illustrate the difficulties inherent in comparative cost analysis. The authors fault the basic data as incomplete, unsystematic and lacking in sufficient detail. Budgets often cover more than actual expenditures and existing facilities and equipment are rarely taken into account. Large variations exist in funding, financing and accounting for joint and shared costs. Many projects are not completely new additions to existing systems and may reduce costs elsewhere. Finally, they note the general difficulty of defining educational inputs and outputs for comparisons between systems. An additional critique of media cost studies (Carnoy & Levin, 1975) pointed out that reported costs in the literature were often projected, rather than historical costs. Also, data were usually supplied by the agency conducting the project and therefore open to some question. Also noted as problems were the tendency of researchers to "give the benefit of the doubt" to the new media and that often complex formulas obscured data that were intrinsically flawed. In 1976, Carnoy attempted to correct these flaws by creating a formula for both cost-effectiveness and cost-benefit analysis. However, the international case studies used to exemplify his methodology are hard to interpret, because only the largest categories of expenditures are used and because costs are given in national currency. This study is significant because it attempts to offer a method of quantifying the effectiveness of mediated instruction, in order to correlate effectiveness and cost. This study also provides some cost comparisons of educational television in international settings.

Working from a methodology developed for general educational costing (Coombs & Hallak, 12972), Jamison and Klees (1975) and Jamison et al. (1976, 1978) created a relatively simple, but exhaustive, set of formulas for cost-analysis of educational television systems that expresses final expenditures in both cost per student and cost per student per hour of instruction. The application of these methods in analyzing the cost of the Stanford ITFS project will be discussed below (Jamison et al., 1978). Although the system is for K-12, another good example of the application of this cost analysis method is the study done of the ITV project in American Samoa (Schramm, Nelson & Betham, 1981).

McCabe (1979) also provides a general formula for determining costs in non-traditional education via television. This report indicates that serving a new clientele through television requires the creation of a new system, rather than the replacement of lectures with television programs. Costs for educational television are divided into three areas: development or acquisition of materials, delivery system and organization, and actual delivery of services. Unlike Jamison et al. (1978), McCabe's formula provides a cost per student per course. He also has a summary chart comparing traditional education to television-centered instruction, showing the cost per course of traditional education between $75-$100 per student and $40 per student for television. A recent, brief article by

Van der Drift (1980) also works on a cost method for educational television that expands McCabe's (1979) cost breakdown. This study presents four cost areas: development and design of materials, production, distribution or delivery and presentation. However, Van der Drift arrives at a cost per student per hour, as Jamison et al. (1978), rather than per course (McCabe, 1979). Van der Drift reports student per hour costs of $2-$6. He also reports non-broadcast product costs of $245-$1,995 and broadcast quality production costs of $15,000-$35,000 for half hour programs.

In addition to cost-analysis methods, another important consideration is the manner in which educational institutions are compensated for television students. Goldstein (1980) summarizes the issues of financing ITV on both the federal and state levels. He notes that governmental policies dealing with instructional television are conspicuous by their absence and concludes that what policies exist discourage both students and institutions from investing in instructional television. Excepting the support provided by the National Institute for Education and the Fund for the Improvement of Postsecondary Education, Goldstein cites the restrictions on reimbursement to students for ITV courses by the Veterans Administration and the fact that the 51 state and federal statutes on student grants and loans generally ignore ITV. Additional negative factors include the lack of uniformity in the accreditation of ITV coursework and state aid formulas for institutional funding that do not permit a full count for ITV students. Goldstein & Salomon (1981) and Goldstein (1982) provide summaries of recent federal budget cuts in ITV support.

Munshi (1980b) discusses the primary sources of income from ITV: tuition, state full-time equivalent reimbursement and lease/purchase fees for institutions producing telecourse packages. Munshi cites an average tuition range from $34-$83 per student per course, with breakeven enrollments ranging from 10-250 students per course. Lease/purchase arrangements range from fee-only leases averaging $32 per student, to purchase agreements averaging $3,000 per telecourse for three-year, unlimited use. In studying 19 colleges and universities that used ITV, Munshi (1980b) found that 12 broke even or made money, while seven lost money. She concluded that television courses are cost-effective only with tax support through state aid or grant funding or when compared to traditional on-campus instruction. Munshi and Stone (1980) provide a universal formula for institutions to determine their particular breakeven enrollment for a telecourse.

MODEL SYSTEMS

Some of the research encountered in this review attempted to create, and then cost out, model systems for different delivery technologies. Models for individual delivery systems are discussed under the appropriate section below. Although advances in technology and the recent ravages of inflation render most of the actual cost figures obsolete, this group of studies provide useful guidelines and formats for planners interested in creating their own systems. Current salary surveys, such as those undertaken by the International Television Association (ITVA Salary Survey, 1981), the Corporation for Public Broadcasting (Salary Report, 1980) and Videowriter ("Freelancer", 1981), can provide current salary levels for television personnel. In addition, equipment magazines such as Educational and Industrial Television, Videography, Audiovisual Communications and Broadcast Management and Engineering, have intensive listings of hardware manufacturers and vendors, as well as publish semi-annual, comparative equipment listings for cameras, videotape recorders, lights, monitors, transmitters, et cetera. These current costs can then be fitted into the appropriate categories in the models.

The Educational Policy Research Corporation of Syracuse University developed a statewide model for each of the television-centered delivery systems (Instructional Television, 1976). Assuming a base of 1,400 schools, the costs of their models range from $51,488,900 for a videotape system to $8,909,250 for an open broadcasting system. The mixed cable and videotape model was $25,633,340, while the cable model alone was $20,069,450. The costs of the other models were $20,225,750 for satellite delivery and $17,134,680 for ITFS. Broadcast programming for six hours per day was calculated at $3,240,000. Programming cost for each of the other systems was $12,960,000. The authors also itemized cost categories for major system components, such as personnel, equipment for production, distribution and reception, programming and administration.

This report concluded that programming costs were the dominant cost feature of each model. Satellite distribution appeared to have the highest degree of sharable costs to the schools. Scheduling flexibility and local control were judged to be the central factors in teacher acceptance. The authors also noted that the existing communications infrastructure in a particular area was very relevant to the type of system that should be chosen. An early report on model systems (Cost Study, 1968; Sovereign, 1969) provides detailed cost categories for television-centered delivery systems at the local, city, metropolitan, state and regional levels that would be useful in projecting cost areas for future systems. However, the actual cost data are obsolete.

Some cost elements, such as programming and production costs, remain relatively constant regardless of the actual delivery system. Munshi & Stone (1980) outline four levels of complexity in the production of a standard 30-program, 30-minute-per-program telecourse and the costs and production time of each level. National telecourses, such as The Growing Years, cost between $600,000 and $1,000,000 and take up to two years to develop and produce. Project: Universe and Oceanus: The Marine Environment, designed for a regional/national audience, cost $400,000-$600,000 and take 12-18 months. At the local/regional level, a telecourse such as Family Portrait may cost $200,000-$400,000 and have a 6-12 month production time. Local productions, Home Gardener, for example, may cost $75,000-$200,000 and be completed in three to six months. Munshi & Stone also list the members of the teams for design, print and television production and validation. Their information is confirmed in similar reports by the Dallas County Community College District (ITV Closeup, 1979), Shulman (1981), Walker (1979) and Zigerell et al. (1981).

Munshi & Stone (1980) also cite a cost of $30,000 and a six-month timeline for the production of the "wraparound" instructional print materials for existing television series such as Cosmos and The Adams Chronicles. Those figures are confirmed by Richardson (1979). Variations in telecourse lease/purchase agreements, ranging from fees of $34 per student, to purchase arrangements for unlimited use, averaging $3,000 per telecourse, are reported by Munshi (1980b) and Beatty (1979).

The major cost components in telecourse production are equipment and personnel. Stalcup & Hall (1978) summarized the costs associated with the operation of a television production studio. They found the capital equipment for a broadcast studio ranged from $500,000 to $2,500,000. Personnel cost varied from $250,000 for a staff of 20, to $600,000 for a 50-person, large station. Operating budgets were $50,000-$200,000. In closed-circuit studios, capital costs were $30,000-$500,000. Staff costs were $30,000-$278,000 and operating funds were $80,000-$700,000. Dordick et al. (1979) report similar figures. Stalcup & Hall (1978) also concluded that a closed-circuit studio, both large and small, could produce programs at a cost of $5,000-$5,500 each.

INDIVIDUAL SYSTEMS AND CASE STUDIES

BROADCASTING

OPEN BROADCASTING

Although the oldest television-centered delivery system is live, open broadcasting by public and commercial television stations, videotape production techniques have effectively eliminated this system in a "pure" form. Open broadcasting is now almost a completely "mixed" system, combining broadcasting with videotaped programming. In addition, educational institutions that use broadcast, videotaped telecourses usually make copies of those programs available to students who were unable to view the program during the broadcast time. McAuliffe (1978) reported on seven community colleges in Connecticut that apparently rely only on broadcast telecourses. The annual budget for the delivery of six telecourses was $25,000. The lease fees per course, per college ranged from $50 to $500. McAuliffe also noted that the operation became self-sustaining at a fee base of $40 per student per course.

INSTRUCTIONAL TELEVISION FIXED SERVICE (ITFS)

In a 1979 report, Curtis delineated in detail the technology of ITFS. He also computed an annual cost per student for ITFS serving adult learners. Per student costs for graduate school operations averaged $114.25 and $13.61 for medical schools. He also cites an average of $5.67 per student in K-12. He attributes the wide range of annual per student costs to the larger populations using ITFS in K-12 and medical schools. Curtis (1979) concluded that ITFS is the most cost-effective of the broadcast delivery systems.

Lent (1977) compared ITFS with live lecture, videotaped lecture and independent study. Based on 2,500 students per semester, he found per student per course costs of $96 for ITFS, $195 for live lecture, $83 for videotaped lecture and $95 for independent study. Lent also reported that although ITFS had the highest initial investment, it had the lowest cost for additional courses.

One of the most complete case studies of ITFS for adult education is provided by Jamison et al. (1976, 1978). This study involves a cooperative effort between Stanford University, Golden Gate University, the College of Notre Dame, San Jose State University and several business locations in the greater San Francisco Bay area. Students can earn various certificates and degrees through this program, including a Master's degree in engineering. Jamison et al. include complete cost data and comparative tables on the setup and operation of the Stanford system. They arrive at an over cost per student per hour of $5.70 to $6.80, depending on the capital interest rate used in the cost equations. A report using more recent data (Instructional Television, 1976) noted a cost per student per hour of $1.63. Jamison et al. also discuss the relative importance of the interactive component of ITFS instruction and briefly mention that, although the system is designed to broadcast live lectures, some students can view tapes of these classes at other times. They also note that the capital costs of this system compares favorably to a new ITFS facility constructed by the University of Southern California ($750,000, Dordick et al., 1979). The cost per student per hour of the USC operation has been reported at $5.01-$11.13 (Instructional Television, 1976).

SATELLITES

Satellite delivery is effectively a mixed distribution system. There are no reports of any attempts at live broadcast instruction, using satellites as relays. Polcyn (1979) outlines the results of the Educational Satellite Communications Demonstration with the three Applications Technology Satellites (ATS) used in experiments in Alaska, Appalachia and the Rocky Mountains during the early 1970's, and appends an extensive bibliography on those efforts. Polcyn cites hourly satellite transmission costs ranging between $90-$430, depending on amount of use and time of day. That general range was confirmed by Graff (1980) and West (1980). Polcyn also provides costs for earth station receivers from large, 10-meter receivers for both two-way audio and video for $400,000, to small, two-meter, audio only receivers for $15,000. West (1980) cites similar costs. A recent article indicates that satellite relay charges have been reduced ("SECA to Feed", 1982). The Public Broadcast Service, through its Public Service Satellite Consortium, offers satellite time for instructional television at $148 per hour.

One of the most extensive instructional satellite systems currently reported is the operation of the Appalachian Community Service Network (ACSN), a continuation of the Satellite Demonstration Project (Gaudreau & Perrit, 1981). Summarizing the work of Bramble (1976-1977), Gaudreau & Perrit report a cost of $2,070.37 per student per course. They note that while the experimental nature of the project causes high cost, they compare this figure with the $1,624 per student per course in traditional classes at the University of Kentucky. Using Satcom-1, the authors project a per student per course cost of $350 when the system is fully operational. The system is designed for adult learners in both graduate and undergraduate courses and for continuing education for engineers and nurses. The system incorporates leased telecourses, with support from classroom discussion groups and some location production. Recent updates on ACSN ("ACSN Delivers", 1981; "Alaska Low Power", 1982) indicate that the network is moving to Satcom-111R and will be offering its courses nationwide over cable.

CABLE

Curtis & Pence (1979) describe the development of cable, including the rules and regulations of the FCC governing cable operation. In particular, they delineate the requirements for educational access channels on systems over 3,500 subscribers. They summarize several case studies, including a comparison of ITFS and cable in the Shawnee Mission Public Schools of Kansas City, Kansas. Although a K-12 system, and outside the direct scope of this review, the cost comparison for these delivery systems is significant, since costs other than delivery were essentially equal. The cost per student per hour was $4.40 for cable delivery, compared to $5.12 for ITFS. They also summarize the interactive cable project for senior citizens in Reading, Pennsylvania ("Test and Evaluation", 1976), but do not provide any cost information.

A negative experience with interactive cable in an adult education context has been reported (Greene, 1979) about the Warner Communications QUBE system in Columbus, Ohio. This study outlines the general costs and operation of the Higher Education Cable Council that was formed by six local colleges in the Columbus area. These colleges leased program material. Greene found the essential failure of the system due in large measure to lack of institutional support and not taking full advantage of the system's interactive capability.

COPY SYSTEMS

VIDEOTAPE: OPEN REEL AND VIDEOCASSETTE

Because of the popularity of videocassettes, both in the 3/4 inch and 1/2 inch formats, open reel videotape is primarily used for the regional and national distribution of telecourses in broadcast format, two-inch videotape (Munshi, 1980b). The State University Resources for Graduate Education Project (SURGE) of Colorado State University (Wagner, 1975) did operate on the basis of videotaping regular lectures. The question of format or open reel or videocassette is not addressed. Adult learners could receive an MA in business, engineering and some of the sciences through the SURGE project. Wagner does an extensive cost analysis of the videotape project and reports a cost of $4.30 per student per hour.

VIDEODISC

Wood & Wooley (1980) compare regular, fixed-pace television with the videodisc. They provide detailed explanations of each videodisc system and outline capabilities and limitations. Their charts show price comparisons for both home and industrial versions of videodisc systems, ranging from $400-$4,000. This report also has an annotated bibliography on the uses of videodiscs and an extended general bibliography. They conclude that the random access, stop and slow motion capabilities of videodiscs hold great promise for educational programming, but they note that the technology needs standardization.

MIXED SYSTEMS

Many of the operations of television-centered instructional systems use more than one method of delivery. As noted earlier, some systems such as open broadcasting, open-reel videotape and satellites are, or have become, inherently mixed modes. The most common mix is the supplementary use of videocassettes of broadcast telecourses to provide learners with the opportunity to review programs, or to initially view programs that were missed during the broadcast schedule.

The University of Mid-America and its associated colleges use this mix of broadcast and tape (Sell, 1975; Kiesling, 1979). Kiesling does a complete cost analysis of the historic expenditures for UMA and campuses in Iowa, Nebraska and Missouri. He derives a per student per course cost of $410 for Iowa, $196 for Nebraska and $722 for Missouri. The Iowa enrollment was 318 students, Nebraska - 1,516 and Missouri - 344. Operating at maximum capacity, Kiesling estimates a per student per course figure of $96 for Iowa, $54 for Nebraska and $53 for Missouri. He also provides an extensive cost chart comparing open universities and traditional education and concludes that television instruction is 20%-30% cheaper than traditional, undergraduate lectures. Finally, Kiesling compares the per student per course costs at UMA to the $39-$69 figure for the British Open University, and the $48 cost at Chicago's Television College.

Another project using a mix of open broadcasting and tape is the Wayne State University Studies and Weekend Course Program (Feinstein & Angelo, 1977). Designed to "provide an educational environment for working adults" (p. 3), the entire project is structured to fit the work schedules and other time constraints of the adult learner. The cost per student, $65 (Goldin & Bear, 1979), confirms the general range reported for UMA.

Stepp (1981) reports a program in South Carolina that uses ITFS broadcasts with videotape and interactive telephone connections, in which adults can earn an MBA or an MS in engineering. The cost of the higher education component of the South Carolina project, reported by Goldin & Bear (1979), was $103.70 per student. The cost per student per course for all students (1,691,699) in the South Carolina system was $5.83.

In 1979, the Alaska State Department of Education undertook an examination of the programming, management and costs of eleven instructional television networks in the United States (Goldin & Bear, 1979). This report summarizes the total capital costs, network operating expenses and costs of the instructional television component. Goldin & Bear also analyze the comparative strengths and weaknesses of each network. They conclude that instructional television can accommodate a wide variety of learners, in both distance and urban settings. They indicate that in selecting a delivery system, consideration must be given to the interrelation of target audience, total system services and local education institutions, because no single system seems superior. They also note that the most effective use of instructional television exists where it is supported by local educators who participate in the decision-making process. Finally, Goldin & Bear found that, while the cooperation of instructional television with public broadcasting seems the most workable arrangement, some learners have programming and schedule needs best served by local, non-broadcast distribution.

Goldin & Bear provide raw cost data and a bibliography on each system. The categories of expenditures reported are large, but useful for comparisons. The following summary shows their derived cost per student for those networks offering higher (H.E.), continuing (Cont. Ed.) and adult basic education (A.B.E.). Although not specified, comparison with other data indicates that these are per course, rather than annual costs.

NETWORK	H.E.	Cont. Ed.	A.B.E.
California (Coastline Comm. College)	$78.75		
Maryland	$315.58	$33.00	$4.14
South Carolina	$103.70	(Teacher Cont. Ed = $120.82)	
Kentucky	$426.00		$39.00
Oregon	$108.00		
Indiana	$65.00		
Univ. of Mid-America	$1,097.00		

(After Goldin & Bear, 1979, pp. 32-35)

Lists of the institutions in the United States that use television-centered instructional delivery systems are available in Munshi (1980b), Gruebel and Robinson (1980), Dirr (1981) and Lewis (1982).

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The primary conclusion that appears indicated by this review is that conclusions about the actual costs of any of the delivery systems discussed are not possible. Schramm's call, in 1967, for uniform, accurate, complete and comparable cost data has been echoed by investigators in this field ever since (Carnoy, 1976; Jamison & Klees, 1975; Jamison et al., 1976, 1978; Lent, 1977; Van der Drift, 1980; Munshi, 1980b).

And it is not as though the methodology needs development. Five years after the first work of Jamison & Klees (1975) and Carnoy & Levin (1975), Munshi (1980b) still finds that each "institution seems to have had difficulty devising a cost accounting system that reflects its costs and revenues accurately and none of the accounting systems was comparable to another" (p. 23). Even with "comparable" categories such as costs per student per hour, the variations, from several cents to hundreds of dollars, seems to indicate that some organizations are efficient in the extreme, or that the raw data are not extremely efficient at reflecting the actual costs.

While comparisons of cost between projects are important, a more critical area of comparison is overall cost with educational effectiveness. Only one study (Carnoy, 1976) made any attempt to match system costs with educational outcomes. The potential economies of television-centered delivery systems, particularly in large-scale applications, are irrelevant without a method of correlating those economies with the learning effectiveness of each system. Without some kind of correlation method to determine true "cost-effectiveness," comparisons of different delivery systems with each other, or with traditional education, seem somewhat pointless.

Another problem for educational planners is the transient nature of cost data. The rapid advance, particularly in the last two to three years, in the sophistication of the delivery hardware obsolete cost figures as fast as they are published. And inflation and regional differences make personnel salary data almost as ephemeral. In addition to monetary figures, a method of quantifying costs in terms of technical specifications for hardware and person hours (weeks, months, etc.) by job category should be developed for reporting case study information and for use in model systems design. This would slow, to some degree, the obsolescence of monetary figures and provide both technical and personnel benchmarks for the creation of new systems. The models themselves need extensive updating, to reflect the advances in both the technology and production techniques.

The literature contained no reports on the actual development of a telecourse. Only the gross figures on development and production of programming for higher education projects are available. Case studies outlining the actual line item costs, time for each production process, number and kinds of personnel required, et cetera, are needed to provide a base of raw data on which to build.

Finally, few of the delivery systems described in the model or case study material seemed designed for the needs of adult learners, yet of those that reported information about their students, the majority were usually adults. And none of the studies covered in this review even mention the possibility of unintended consequences (Richardson, 1981), let alone examine those possibilities. For television-centered delivery systems to fulfill their promise, our expectations and the requirements of shrinking funds and emerging new populations of learners, we have to understand all the capabilities and limitations, all the costs, of these methods, in order to apply them in the most effective and efficient fashion.

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